Propulsion plant feasibility study report subtask 2: propulsion plant technical anlaysis and determination of standards candidates.

M. Rosenblatt and Son, Inc.

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SHIP PRODUCIBILITY PROGRAM
TASK S-1
PROPULSION PLANT
FEASIBILITY STUDY
REPORT
SUBTASK - 2
PROPULSION PLANT TECHNICAL ANALYSIS AND DETERMINATION OF STANDARDS CANDIDATES

Prepared for

BATH IRON WORKS

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4.0 PROPULSION PLANT ANALYSIS AND DETERMINATION OF STANDARDS CANDIDATES

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4.1 SUMMARY

4.1.1 GENERAL

This Task consists of a technical evaluation of the propulsion plants which reflect the requirements of the shlps forecast to be ordered in U.S. Shipyards to 1986. The main purpose of the Task is to select viable standards candidates for further economic analysis.

The standards candidates to be evaluated were based upon experience gained in the following:

1. Preparation and determination of the forecast, Task 1, of this study.
2. Literature Research of technical publications and papers.
3. Consultations with shipbuilders, equipment manufacturers and ship owners and operators. These included visits to their facilities.
4. Consultations with foreign shipbuilding industry representatives.
5. Research concerning standards utilized in other industries such as oil drilling, power plant, building, etc.

The results of the forecast specifically showed that:

1. The quantity of ships to be ordered from U.S. shipyards indicates that the shipbuilding industry will thrive during the next ten to fifteen years. The use of propulsion plant standards may help reduce the costs.

2. The emphasis in selecting standards for propulsion plants should be placed on steam turbines first and then on diesels and gas turbines.

3. The sizes of propulsion plants for investigation should be grouped as follows:

Steam (239 Plants to 1985)

15,000	-	17,500 SHP	(13 plants)
24,000	-	26,000 SHP	(76 plants)
28,500	-	32,000 SHP	(27 plants)
36,000	-	40,000 SHP	(92 plants)
43,000	-	45,000 SHP	(20 plants)
50,000 SHP			(11 plants)

Diesel (90 Plants to 1985)

7,000	HP	(26 plants)
14,000	HP	(50 plants)
28,000	HP	(14 plants)

Gas Turbine (119 Plants to 1985)

12,500	HP	(32 plants)
25,000	HP	(11 plants)
30,000	HP	(39 plants)
35,000	HP	(16 plants)
40,000	HP	(8 plants)
60,000	HP	(13 plants)

4.1.2 METHODOLOGY

4.1.2.1 The definition of the word "Standard" was established for the purposes of the feasibility study; and the types and levels of standards were defined as well. Briefly, the definition established the "standard" as a formal document and the various characteristics or conditions contained in the standard were labeled "standards parameters".

4.1.2.2 The types of standards refer to a specific area of concern, and they are classified as follows:

1. Performance
2. Operating
3. Interface
4. Packaging
5. Software

4.1.2.3 The levels of standards specify the degree of detail addressed by the standards. For this study, the levels are classed as follows:

1. Total package
2. Major system
3. Sub-system
4. Component

4.1.2.4 The criteria to be utilized in the selection of standards candidates were defined. The many factors and their relative influence yere synthesized into technical feasibility, economic potential and industry acceptance.

4.1.2.5 The propulsion plants under consideration were then defined and a waterfall chart was prepared for each of the three major systems -- steam, diesel an-d gas turbine. . These charts were utilized as tools to list the potential candidates. Figure 4-1 is the chart for a steam plant.

4.1.2.6 A matrix was developed utilizing the "type" and "level" as coordinates and applying the elements of the propulsion plant waterfall chart to list the standards parameters. In other words, standards parameters were determined for the major propulsion plants for each type of standard at all levels. Table 1 provides this matrix for the steam propulsion plant.

4.1.2.7 From this matrix, a listing of standards parameters was developed and the evaluation criteria applied to each The method of application was a numerical grading system which accounted for the relative merits of technical feasibility, economic potential and industry acceptance. Table 4-2 shows the steam plant evaluation.

4.1.2.8 An analysis of the gradings determined the standards parameters with the greatest potential.

4.1.2.9 These parameters were then grouped into logical categories for selective economic analysis in the next Task of this study.

4.1.2.10 For the purpose of this feasibility study, parameters which showed the highest potential were selected for further economic analysis. Those candidates which ranked lower than those selected may still be included in the standards program at a later date should they deserve consideration.

4.1.3 SELECTED STANDARDS PARAMETERS

The selected parameters generally lend themselves to be identified with four different categories: Total Propulsion Plant, System/Equipment Nodules, Equipment Envelopes and Major individual Equipment/Components.

The potential of each standards parameter was evaluated for inclusion into a "standard" at its respective "type" and "level". A review of the parameters with the greatest potential indicates that the same type parameters appeared at more than one level and many of the different types are interdependent. Since many similarities exist between the parameters at different level and types, it was decided to group them into four logical categories.

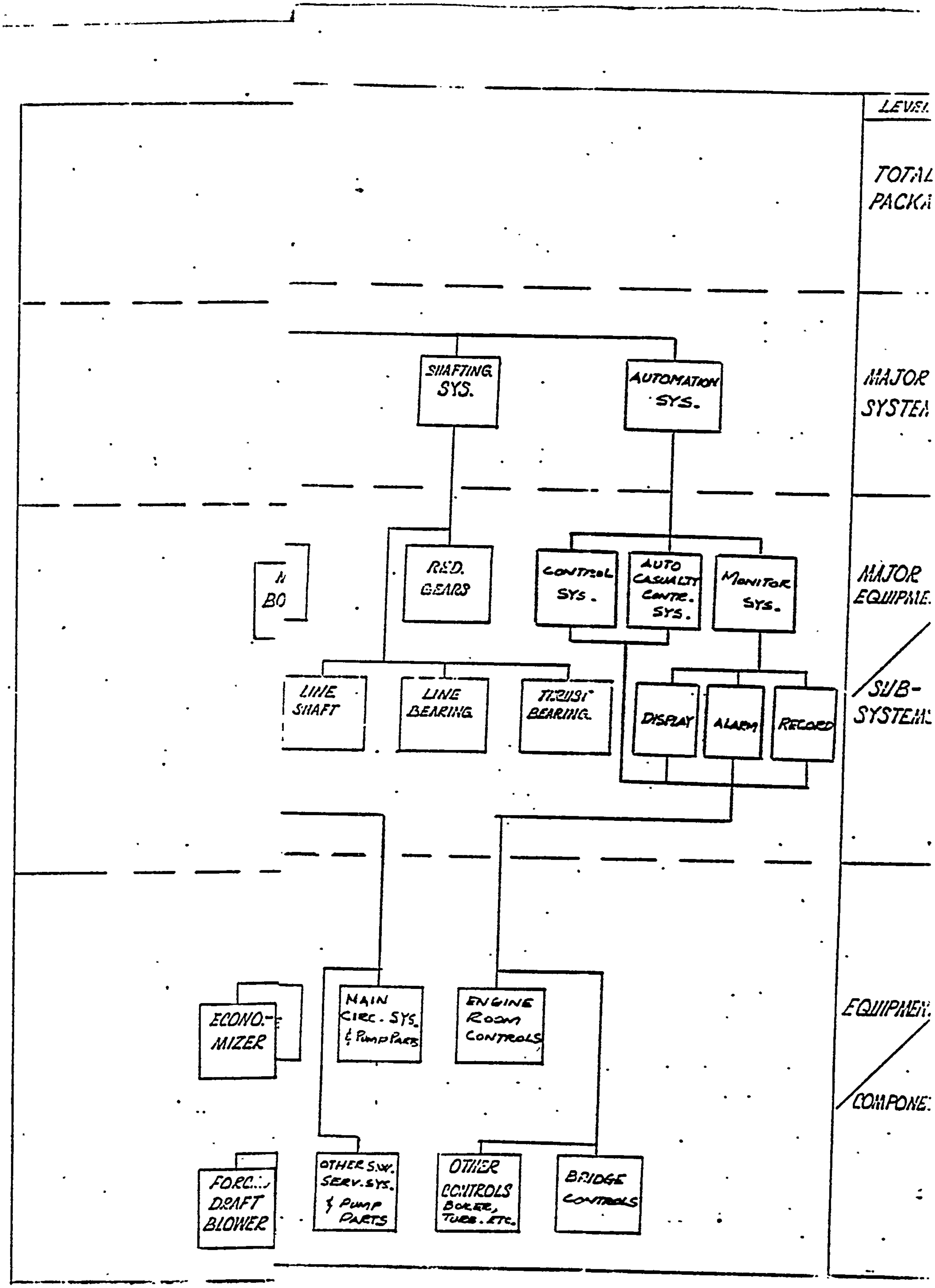

Figure 4-1
Steam Propulsion Plant
System Waterfall Chart

TYPE / LEVEL	PERFORMANCE	OPERATION	INTERFACE	PACKAGING	SOFTWARE
Package & Plant	SHP RPM Fuel Rate	Steam Conditions [illegible] Conditions Heating Stages # of Boilers	Engine Room Envelope Engine Room Arrangement Shaft Size Engine Room Weight & C.G.	Structural [illegible]	Heat Balance Std. Specs Procurement Specs Coast Guard [illegible] Std. Dwgs. Arr. Dwgs Piping Dwgs Inst. Dwgs	[illegible]
• Major Systems Steam Sys.	Losses – Efficiency	Steam Conditions ; Pipe Sizing & Material	Pre-formed Pipe; Piping Interfaces ; Bulkhead/Stop Valve Location	Pre-formed Pipe	Calculations & Heat Balance
Cond. Sys.	Losses – Efficiency	Condensate Conditions ; S.W. & Steam Cond.	Piping Interfaces ; Pre-formed Pipe	Pre-formed Pipe	Heat Balance
Feed Sys.	Losses – Efficiency ; Heat Transfer	Feed Conditions ; Steam Conditions	Piping Interfaces	Pre-formed Pipe	Heat Balance
Aux. Sys.		Aux. Svc. Inputs – Temp. & Pressure	Aux. Piping Locations with Mn. Sys.		
Line Shaft Sys.	HP ; Torque ; RPM	Material Std ; No. of Bearings	Shaft Size (Intermediate) [illegible] [illegible] Location of Bearings [illegible]	Packing Support (in Shipping)	Calculations ; Material Spec. ; [illegible]
S.W. Sys.		S.W. Inputs into Mn. Sys. – Temp., Pr. & GPM	S.W. Pump Interfaces with Mn. Sys.		
• Major Equip./ Sub-Sys.					
Boiler	Capacity – #/hr. Firing Rate Eff. – % Fuel Rate Generating Surface	S.H. Steam Conditions, Stack Gas Temp. S.H. Type, Inlet Water Temp. No. of Burners, Inlet Water Press. [illegible]	Size – Location Weight – Limiting Location – S.H. Outlet Piping to Interface – Fd Inlet Locations – Fuel Lines	Shipped Assembled	Installation Dwgs. – Approved Operation & Maint. Manuals Std.
Mn. Turbines	Steam Rate – #/SHP-hr. (Conv. [illegible]) HP (matching total pkg) RPM	Steam Conditions Back Pressure Extraction Temp. & Pressures	Size & Wt. of Turbines (Limiting) Mounts – [illegible] w/Condenser Location of [illegible] Exhaust (& Size) Size & Location of Steam Lines Foundation Bolting	Mounted on [illegible] Turbine shipped assembled Lifting Lug Std.	Operation & Maint. Manuals Std. Installation Dwgs. – Approved Performance Curves
Condenser	Capacity – #/hr. Cooling Rate Heat Transfer Coefficient	Vacuum Temperatures – Steam Condensate Circ. water (inlet & outlet) Circ. water GPM	Circ. Water Inlet & Outlet Location & Size Steam Inlet Location & Size Condensate Out Location & Size [illegible] Size & wt. of Condenser	Shipped Assembled Module with Turbines & Air Ejectors	Specs. Dwgs. – Installation
Condensate Pump	GPM Rated Head	RPM PRIME MOVER – Motor Power Required Centrifugal	Limiting Size & Weight Suction & Discharge Location & Size Foundation & Bolting Controls	Pumps as module with controls & piping Shipped Assembled Piped to Interface Location	Specs. Dwgs. Tech. Manuals
1st stage Htr.	Heat Transfer Coefficient Efficiency Capacity	Steam Rate of Flow, Temp. & Pressure Temp. & Pressure of Condensate	Combined with Steam Dsg. Fd. & Gland Cond. Size, wt. & C.G. Steam Inlet-Outlet Locations & Sizes Foundation Support & Bolting	Modularized Shipped Assembled	Heat Transfer Data Dwgs. Tech. Manuals Specs.
Air Ejector	Ratio of Compression Pounds of Water Vapor Per Pound of Air Leakage	Steam Saturation Pressure at Air-Vapor Allowable Pressure @ Air-Vapor Outlet	Size & Location of Interface Piping Size & Weight of Air Ejector Location of Interface Bolting	Attached to Condenser Shipped Assembled With Interface Piping	Performance Curves Installation Dwgs. Specs. [illegible]
Steam Dsg. Feed	Common With First Stage Heater	Performance Operation Interface Packaging and Software Same as Similar			
Gland Leakoff Condenser					
2nd stage Htr.	SEE FIRST STAGE HEATER				
D.C. Heater D.F.T.	Dissolved Oxygen Content of Feed Capacity	Feed Storage Steam Inlet Conditions Condensate-in, Feed-out Conditions	Size & Weight – Limiting Size & Location of Interface Piping Foundation & Support Locations	Shipped Assembled with Vent Condenser Interface piping led to Location as Envelope	Installation Dwgs. Specs. Operating Manual.
Mn. Feed Pump	Rated Capacity Rated Pressure	Prime Mover – Aux. Turbine – Stm. Cond. & BHP Suction & Discharge – Temp. & Pressure Pump Type	Pumps as Module with Controls & Pipe Limiting Size & Weight Foundation & Bolting Controls Suction & Discharge Locations Size	Pumps as Module with Controls & Pipe Shipped Assembled Piped to Interface Locations	Specs. Dwgs. Tech. Manuals
3rd stage Htr.	Capacity Efficiency Heat Transfer Coefficient	Steam Rate of Flow, Temp. & Pressure Temp., Pressure & Rate of Flow of Feed	Combined with Fourth Stage Heater Size, wt. & C.G. Steam Inlet – Outlet Size & Locations Foundation, Supports & Bolting	Modularized Shipped Assembled	
4th stage Htr.					
L.O. Service Sys.	Capacity	L.O. Conditions In & Out	Location & Size of Piping In & Out Equipment Sizes	Coolers & Strainers Combined Pumps & Sumps Combined	Piping Dwgs. Sys. Specs. Operating Manual
L.O. Purifying Sys.	Oil Purity			Modularized	
F.O. Service Sys.		F.O. Conditions In & Out			
Aux. Turbines	BHP	Steam Conditions	Steam Inlet Size & Location [illegible] – Outlet Size & Location Limiting Size & Load Weight Foundation & Bolting – Coupling Method	Pressure [illegible]	Installation Dwgs. Specs. Tech. Manual
Control Sys.	Functions from no. of Points	Type of Control: no. of Trips Solid State no. Automatic Economy [illegible] Bridge/Engine Room [illegible]	Pressure Volts Air, Elect., Hydraulic Equipment Size of Consoles	[illegible]	Troubleshooting Manual Specifications
Line Shafting	Torque	Hollow or Solid Material	Location of Thrust & Line Bearings & Stern Shaft Tube Length, Diameter & Weight	N/A	Calculations Vibration Analysis
Gears (Red.)	HP to 60,000 HP in steps	No. of Reductions (2 or 3) [illegible] & Load Tooth by Size "K" Factor	Internal Thrust Bearing Size Package & Weight Location of Inlet & Outlet Pinion [illegible] Matched Gears L.O. Inlet & Outlet Locations	Ship Assembled or Matched Packing or Protection	Std. Specs. Std. Dwgs. Std. Calcs.
Thrust Bearing	Thrust Pressure Load Per Square Inch of Bearing Surface	Type – Pivoted Segmented Shoe No. of Shoes Oil Pressure	Limiting Size & Weight L.O. In & Out Size & Location	Shipped Assembled in Protected	Std. Specs. Std. Dwgs.
Line Bearings	Load Per Square Inch of Bearing Surface	Material Lubricating Method L.O. Temperature	Limiting Size & Weight L.O. Locations & Size Clearances		Specifications Drawings
Circ. Pump	Rated Capacity & Head	Power Req'd Material RPM Prime Mover	Suction & Disch. Size & Locations Foundations & Bolting	Combined with Sea Chest & Strainer Module	Specs., Dwgs., & Manual
Other S.W. Services	Capacity	S.W. Pressure & Temp. Cond. S.W. Service Pumps Manifolding	Pipe Size Size & Wt. of Pumps	Module containing Pumps, Controls, Manifold & Piping	Sys. Dwgs. Specs.

Steam Propulsion Plant
Standards Parameters Matrix
Table 4-1
Sht. 1 of 2

TYPE / EVEL.	PERFORMANCE	OPERATION	INTERFACE	PACKAGING	SOFTWARE
Economizer	Heat Transfer	Feed Conditions Flue Gas Conditions	Attached or Not Attached to Boiler Location & Size of Feed Inlet, Flue Gas Inlet & Outlet Limiting Size & Wt. of Economizer	Shipped Assembled Ready for Attachment to Boiler or On Furnace	Specs. Dwgs. – Installation
Air Preheater	Heat Transfer : Capacity	Inlet & Outlet Air CFM & Temp. Flue Gas Conditions	Limiting Size & Wt. Location & Size of Air & Flue Gas Conducts	With Boiler	
Forced Draft Blower	Oil Burned Per Fan, #/hr. CFM ; Static Efficiency Air Pres. In. of Oil, Ex. H. 10	RPM · Blower Type AMP · Drive – RPM, HP Rating Pressure	Controls Limiting Size & Wt. Location & Size of Ducting	Shipped Assembled	
Boiler Controls	Reliability & Maintainability Sensitivity Requirements	Pneumatic, Hydraulic, Electronic ; Fuel, Combustion air, Feedwater Flow; Steam press.; Steam pressure; Water Level; [illegible]	Location of Transmitters Size & Location of Boiler Interface & Controls	Modularized	Specs. Dwgs. Operating Manual
All Press. Boiler	Durability Corrosion Resistance Material Requirements	—— IN BOILER ——		IN BOILER	SPECS. – MATERIAL DWGS.
Turbine		—— IN MAJOR EQUIPMENT STANDARD ——			
Cond.					
Cond. P.					
Air Ejector					
Feed Heater					
Feed Pump					
L.O. Coolers	Heat Transfer Coefficient Losses – Efficiency Fouling Rate	Shell & Tube Type · Segmented Cases, Seal Baffles – Floating Tube Sheet L.O. Inlet & Outlet Temp & Press. S.W.	Limiting Size & Wt. Size & Location of L.O. Inlet & Outlet, S.W. Foundation & Bolting	Combined with Strainer & Other Comps. Mounted on Red. Gear Casing or Sump	Dwgs. Specs. – Material & Dimensions Tech Manual
L.O. Service Pumps	Rated Capacity & Pressure Efficiency	HP Req'd. · Motor RPM · Pressure Developed Prime Mover · Type	Limiting Size & Wt. Size & Location of Suction & Disch. Mounting Interfaces	Mounted on L.O. Sump	
L.O. Strainers	Capacity & Pressure Drop	TYPE – DUPLEX SIZE MESH MATERIAL		Mounted on L.O. Cooler	
[illegible] Heater	Heat Transfer Coefficient Capacity	CFM Heated Lube TYPE Temp of L.O. Inlet & Outlet, Steam	Limiting Size & Wt. Location & Size of L.O. Inlet & Outlet, Steam Foundation & Bolting	L.O. Purifying Sys. Module	
L.O. Purifier	Capacity Clarity of L.O. [illegible]	RPM Centrifugal Prime Mover	Limiting Size & Wt. Location & Size of L.O. Inlet & Outlet, Sludge Outlet Foundation & Bolting ; Location & Size [illegible]		
L.O. Re. Pump	Rated Capacity & Pressure Efficiency	RPM Type Motor Driven Prime Mover	Limiting Size & Wt. Location & Size of Suction & Disch. Foundation & Bolting		
F.O. Service Pumps				F.O. Service Sys. Module	
F.O. Heaters	Capacity Heat Transfer Coefficient Efficiency	Temp & Press. of F.O. Inlet & Outlet Temp & Press. of Steam Inlet Temp of Condensate Outlet [illegible]	Limiting Size & Wt. Location & Size of F.O. Inlet & Outlet, Steam, Cond. Foundation & Bolting		
F.O. Strainers	Capacity & Pressure Drop	Duplex Size Mesh Material	Limiting Size & Wt. Location & Size of Suction & Disch. Mounting Interface		
Aux Turbine Parts	Durability Corrosion Resistance Material Requirements	—— IN AUXILIARY TURBINE STANDARDS ——			SPECS – MATERIAL DWGS.
Engine Room Control Console	Reaction Time No. Of Control Functions	No. of Monitoring & Alarm Points Method of Control: Pneumatic, Hydraulic, Electric, Mechanical Degree of Automation	Limiting Size & Weight Environmental Req'mts. – Temp., Humidity Interface Locations		Specifications Arrangement Dwgs. Operating Manual
Bridge Control Console					
Various Control Panels		Type of Control Actuators Control Power Characteristics Environmental Characteristics No. of Control Functions [illegible]			
Main Circ Pump Parts	Material Requirements	—— IN MAIN CIRCULATING PUMP STANDARD ——			SPECS – MATERIAL DWGS.
All S.W. Serv. Pump Parts		—— N/A ——			
Piping & Materials		N/A	N/A	N/A	Material Specs

Table 4-1

Sht. 2 of 2

Standards PA P... & Totals / Criteria & Multiplier		A Technical Feasibility	B Economic Potential	C Industry Acceptance
		40	40	20
TOTAL PACKAGE				
STEAM PROP PLANT:				
RPM	40?	20 (1)	23	11
SHP	93.3	40	34.6	12.6
[illegible]	72.3	34 (2)	27.3	11
Steam conditions	96	40	36.7	19.3 (5)
[illegible] conditions	90.3	38	34	18.3
[illegible]	86.7	37.3	32.7	16.7
No. of boilers	96	39.3	29 (4)	17.7
[illegible]	67.3	29.3 (5)	26	13
[illegible]	64.3	29	25.3	10
Shaft size	67.7	29	24	15.7
[illegible]	37.3	8	17.3	11
[illegible]	76.7	26.7	35.3	14.7
Heat balance	86.7	39.3	31.7	19.7
[illegible] spec.	85.7	34.7	32.7	12.3
[illegible] spec.	80.3	32.7	32.3	15.7
[illegible]	77.6	27.7	32	17.7
[illegible]	67.7	20	30	17.7
Std. [illegible]	79.3	27.3	34	17
[illegible]	76	24 (6)	34	19
[illegible]	71.3	23.3 (6)	33.3	14.7
[illegible]	70	24.6	30.7	14.7
[illegible]	73.1	38.1	29	16
MAJOR SYSTEMS				
STEAM SYSTEM:				
Losses – Eff	66	32 (7)	17.3	16.7
Steam conditions	92.5	40	37.3	20
Pipe sizing	91.6	34.7 (6)	36.7	15
Pipe materials	62.6	32.7	20.7	8
Pre-formed pipe	77.7	28 (8)	34.7	14.7
Piping [illegible]	82.6	30.7 (9)	30.7	16
Bulkhead/stop valve location	66	26.7 (10)	23.3	14
[illegible]	86.7	37.3	30.7	16.7
CONDENSATE SYSTEM:				
Losses – Eff	47.3	27.7 (7)	9.3	11.3
[illegible] conditions	76.7	34	29	14.7
[illegible]	66.7	26.7	27.3	10.7
Piping [illegible]	70.7	30.7 (9)	29	12
Pre-formed pipe	65.6	28 (8)	24.7	12.7
Heat balance	86.7	37.3	30.7	16.7
FEED SYSTEM:				
Losses – Eff.	59.3	31.7 (7)	14.7	13.3
Heat transfer	62.7	29.7	26	8
Feed conditions	94.7	38	29.3	17.6
Steam conditions	84.7	37.6	29.3	17.7
Piping interfaces	68.7	30.6 (9)	26	12.1
Pre-formed pipe	65.3	28 (8)	24.7	12.6
Heat balance	88.3	37.3	29.3	12.7
AUXILIARY SYSTEMS:				
Aux. sys. impact	47	20	15.3	11.7
[illegible] piping into [illegible] system	49.1	16.7	20.7	12.7
[illegible] SYSTEMS:				
[illegible]	50	22.7	16	11.3
[illegible] piping into [illegible] system	51.7	19.8	20.7	11.7
[illegible] system				
SHP	91.3	40	34.7	16.6
[illegible]	57.9	21.7	10.7	11.5
RPM	42	22 (1)	9.7	11.3
[illegible]	42	26.7	15.3	2
No. of [illegible]	51.8	15.5	25.3	14.7
Shaft size	57.7	26	29.3	2.6
[illegible]	53.3	27.3	17.3	8.7
[illegible]	61.8	18	26.7	16.4
[illegible]	41.5	20	24	7.5
Weight	50.7	22	22.7	9
Location of [illegible]	61.3	19.3	26.7	15.1
[illegible]	62.7	24.1	25	11
[illegible]	57.6	31.7	22	2.7
[illegible]	77	29.7	26.7	13.6
[illegible]	57.7	20	26	11.7
[illegible] spec.	47.7	26.7	18	4
[illegible]	57	20.7	22.7	14.6
MAJOR EQUIPMENT/SUB-SYSTEM				
BOILER				
Capacity – %.	86	40	29.3	16.7
[illegible] – %	67.3	35.8	20	16
[illegible]	76.6	39.3	30	7.3 (11)
[illegible]	69.1	37.7	22.7	7.7 (11)
[illegible]	79.3	40	26	14.3
[illegible] steam [illegible]	91.6	40	33.3	17.3
[illegible] type	62	37.3	16	9.7 (11)
No. of burners	62.7	57	16	6.3 (11)
[illegible]	65.3	37.3	17.7	7.3 (11)

Standards Criteria & Totals / Criteria & Multiplier		A Technical Feasibility	B Economic Potential	C Industry Acceptance
		40	40	20
MAJOR EQUIPMENT/SUB-SYSTEM				
BOILER (cont'd):				
[illegible]	84	37	32	15
[illegible] temp	50	19	19	12
[illegible]	70	34	29	17
[illegible]	72	33	25	14
[illegible]	57	29	21	7
[illegible] size & weight	82	38	29	15 (9)
[illegible]	76	34 (12)	29	13 (9)
[illegible]	74	34 (12)	27	13 (9)
[illegible] feed [illegible]	74	34 (12)	27	13 (9)
[illegible]	77	35 (12)	30	12 (9)
[illegible]	84	37 (12)	34	13 (9)
[illegible]	78	35	28	15
[illegible]	79	29 (13)	25	15
[illegible]	72	27 (13)	16	12
MAIN TURBINES:				
[illegible]	57	29	15	15
HP	83	40	29	14
RPM	60	33	17	10
Steam conditions	82	38	27	18
Back pressure	63	37	19	12
[illegible]	49	28	15	6
[illegible] size & wt.	72	37	25	10 (9)
[illegible]	75	33	31	11
[illegible]	45	19	19	7
[illegible]	55	23 (12)	26	4
[illegible]	69	38	29	10 (9)
[illegible]	56	25 (12)	20	11 (9)
[illegible]	44	20	21	3
[illegible]	66	33	18	15
[illegible]	67	28	26	13
[illegible]	67	25	24	13
[illegible]	68	29	27	12
[illegible]	77	35	31	11
Performance [illegible]	63	27	25	11
[illegible] spec.	72	34	27	17
CONDENSER:				
Capacity – #/hr	83	39	29	15
[illegible]	55	30	18	7 (14)
Heat transfer [illegible]	69	34	29	6 (14)
[illegible]	65	30	17	18
[illegible] – str.	73	34	22	17
[illegible]	72	31	24	17
[illegible]	71	29 (14)	28	15
[illegible]	70	33	22	15
[illegible] & size	63	29	22	12 (9)
[illegible] & size	49	23 (14)	21	5
[illegible] & size	63	29	22	12 (9)
[illegible] & size	61	29	20	12 (9)
[illegible] size & wt.	73	37	25	11 (9)
[illegible]	74	37	21	16
[illegible]	85	37 (15)	33	15 (15)
[illegible]	72	34	31	17 (15)
[illegible]	71	29	27	14
[illegible] PUMP				
GPM	90	40	35	15
[illegible]	85	37	33	15
RPM	77	37	32	14
[illegible]	90	35	36	19
[illegible]	90	31	32	17
Type – [illegible]	77	33	29	15
[illegible] size & wt.	75	37	25	13 (9)
[illegible]	76	34	25	13 (9)
[illegible]	72	33	27	11
[illegible]	71	31	28	12
[illegible]	90	39	35	16 (15)
[illegible]	85	39	30	16
[illegible]	76	35	28	13 (9)
Specifications	83	37	31	15 (15)
[illegible]	77	37	28	16
[illegible]	77	31	31	15
[illegible]				
[illegible]	57	27	22	3 (11)
[illegible]	40	22	16	2 (11)
[illegible]	91	37	30	14
[illegible]	70	35	23	12
[illegible]	57	27	21	9 (11)
[illegible]	71	36	23	12
[illegible]	71	37	20	14
[illegible]	70	37	22	11
[illegible] size & [illegible]	66	33	21	12
[illegible] size & [illegible]	66	33	21	12
[illegible]	52	24	19	9
[illegible]	71	37	21	13
[illegible]	54	27	23	4 (11)
[illegible]	57	22	23	12
[illegible]	55	22	22	11
[illegible]	77	27	20	12 (11)

Table 4 - 2
Steam Propulsion Plant
Evaluation Matrix
Sht 1 of 6

CRITERIA & MULTIPLIER / STANDARDS PARAMETER & TOTALS		A TECHNICAL FEASIBILITY	B ECONOMIC POTENTIAL	C INDUSTRY ACCEPTANCE
		40	40	20
MAJOR COMPONENT / SUB-SYSTEM (CONT'D)				
AIR EJECTOR:				
[illegible] OF COMP.	59	29	22	9
[illegible]	53	29	18	6
STM. SUC. PRESS. OF [illegible]	61	29	23	9
[illegible] PRESS. [illegible]	61	29	23	9
MOUNTING SIZE & WT.	68	33	25	10
SIZE & LOC. OF [illegible]	71	33	27	11
LOC. OF [illegible]	50	22	20	9
[illegible]	71	33 (7)	27	11
SUPPLIED ASSEMBLED	70	37	22	11
APPD. CERT. DWGS.	61	25	24	12
O&M MANUAL	56	20	25	11
[illegible] COMBINED W/1ST STG. HTR. – SAME STDS. [illegible]	SAME	AS	1ST STAGE HTR.	
2ND STAGE HEATER: [illegible]				
[illegible] HEATER (D.E.?):				
[illegible]	60	29	20	11
CAPACITY	74	37	25	12
[illegible] STORAGE	60	30	20	10
[illegible]	70	39	19	12
[illegible]	71	39	20	12
MOUNTING SIZE & WT.	65	37	17	11 (9)
SIZE & LOC. OF [illegible]	69	30	27	12 (9)
[illegible]	52	25	18	9
SUPPLIED ASSEMBLED [illegible]	69	37	20	12
APPD. [illegible] DWGS.	65	29	25	11
SPECS	65	27	27	11 (7)
O&M MANUAL	59	22	24	13
[illegible] FEED PUMP:				
RATED CAPACITY	80	39	27	14
RATED PRESSURE	80	37	27	16
[illegible]	79	37	23	19
[illegible]	81	39	26	16
PUMP TYPE	79	39	29	11
[illegible]	86	37 (7)	34	15
MOUNTING SIZE & WT.	66	33	22	11 (9)
[illegible]	53	25	20	9
CONTROLS	72	37	23	12
SIZE & [illegible]	69	31	25	13 (9)
SUPPLIED ASSEMBLED	85	39	32	14
SPECS	80	35	29	16 (7)
APPD. DWGS.	71	31	22	18
O&M MANUALS	80	31	33	16
3RD STAGE HEATER:				
CAPACITY	79	37	29	13
[illegible]	44	21	13	10
[illegible]	56	25	21	10
[illegible]	64	34	18	12
[illegible]	71	33	21	17
[illegible]	64	32	21	12
[illegible]	67	30	24	13
[illegible]	50	37 (7)	21	12
[illegible]	66	33	21	8
[illegible]	66	33	23	9 (9)
[illegible]	66	33	19	14 (9)
[illegible]	56	25	21	10
[illegible]	63	37	16	10
SPECS	64	25	23	16 (7)
APPD. DWGS.	61	22	24	15
[illegible] MANUALS	61	22	23	16
4TH STAGE HEATER: [illegible]	SAME	AS	3RD STAGE	HEATER
[illegible] SYSTEM:				
CAPACITY	72	39	24	9
[illegible]	65	34	21	10
[illegible]	61	32	25	4
[illegible]	61	35 (7)	16	10
[illegible]	61	27 (13)	4	10
[illegible]	62	25	19	18
[illegible]	69	33	21	15
O&M MANUAL	53	21	21	11
[illegible] PUMPING SYSTEM:				
CAPACITY	72	37	24	11
[illegible]	47	27	9	11
[illegible]	59	25	22	11
[illegible]	61	29	21	11
[illegible]	61	25	21	4
[illegible]	72	31 (7)	29	12
APPD. [illegible] DWGS.	57	25	17	10
[illegible]	65	33	17	15
O&M MANUAL	53	29	21	13
[illegible] SERVICE SYSTEM:				
CAPACITY	87	37	31	15
[illegible]	74	34	29	11
[illegible]	73	35	25	11
[illegible]	66	31	29	6
[illegible]	79	39 (7)	30	11
[illegible]	61	27	21	13
[illegible]	69	35	19	15
O&M MANUAL	63	27	25	11

CRITERIA & MULTIPLIER / STANDARDS CANDIDATES & TOTALS		A TECHNICAL FEASIBILITY	B ECONOMIC POTENTIAL	C INDUSTRY ACCEPTANCE
		40	40	20
MAJOR COMPONENT / SUB-SYSTEM (CONT'D)				
AUX. TURBINE:				
[illegible]	64	27	25	12
[illegible]	76	36	23	17
[illegible] SIZE & LOC.	67	34	22	11
[illegible]	64	31	21	12
MOUNTING SIZE & WT.	65	36	19	10
[illegible] METHOD	72	34	24	14
CONTROLS	71	35	27	9
[illegible]	54	26	20	9
[illegible] METHOD	60	30	20	10
APPD. DWGS.	67	29	25	13
SPECS	69	33	22	14 (7)
[illegible] MANUAL	73	30	30	13
CONTROL SYSTEM:				
[illegible]	45	16	4	15
NO. OF [illegible]	35	27	6	2
TYPE – ELECTRONIC, ELECTRIC, PNEUMATIC, HYDRAULIC	74	29	34	12
[illegible]	34	24	2	8
[illegible]	46	24	22	10
REQUIREMENTS: [illegible]	54	20	24	10
SIZE OF CONSOLE	56	26	20	10
[illegible] SYS.	55	17	36	2
[illegible]	73	36	20	17
INSTRUCTION MANUALS	44	9	26	6
MANUALS	46	10	36	0
SPECS	45	12	26	7
[illegible] SHAFTING:				
[illegible]	48	24	14	10
[illegible]	55	28	15	12
MATERIAL	46	29	16	1
[illegible]	53	13	25	15
[illegible]	52	16	22	14
[illegible] WT.	47	21	21	5
[illegible]	60	23	26	11
[illegible] ANALYSIS	57	24	23	10
REDUCTION GEARS:				
[illegible]	77	33	27	17
NO. OF REDUCTIONS	57	27	21	9
[illegible]	72	34	25	13
[illegible]	49	27	13	9
[illegible]	75	35	29	11
[illegible]	71	37	23	11
[illegible]	62	31	21	10
[illegible]	70	33	23	14
[illegible]	65	33	21	12 (9)
[illegible]	74	33	25	16
[illegible]	71	33	24	14
SPECS	67	33	22	12 (7)
APPD. DWGS.	59	27	22	10
[illegible]	72	37	27	8
THRUST BEARINGS:				
THRUST PRESSURE	57	27	22	8
[illegible]	57	29	21	7
[illegible]	70	30	25	15
[illegible]	43	18	20	5
[illegible]	60	27	20	13
[illegible]	62	30	20	12
[illegible]	66	32	21	13
[illegible]	70	37	20	13
[illegible]	80	37 (15)	29	14
SPECS	66	31	23	12 (7)
APPD. DWGS.	65	25	29	11
JOURNAL BEARINGS:				
[illegible]	60	27	23	10
MATERIAL	47	30	16	1
[illegible]	80	37	28	15
[illegible]	57	25	21	12
[illegible]	59	30	19	10
[illegible]	69	37	21	11
[illegible]	64	25	22	17
SPECIFICATIONS	57	27	13	17 (7)
APPD. DWGS.	59	27	26	11
[illegible] PUMP:				
RATED CAPACITY	74	37	24	13
[illegible]	76	35	26	15
[illegible]	76	32	29	13
[illegible]	61	27	25	9
[illegible]	80	39	25	16
TYPE – [illegible]	73	39	19	15
MATERIAL	52	34	17	1 (7)
[illegible]	73	39	24	10 (9)
[illegible]	54	21	23	11
[illegible]	53	25	21	7
[illegible]	50	23	19	9
SPECS	69	33	25	11 (7)
APPD. DWGS.	66	28	27	11
[illegible] MANUAL	66	29	25	12
[illegible] S.W. SERVICE:				
CAPACITY	65	29	26	11
[illegible]	47	27	21	10
[illegible]	47	25	17	5
[illegible]	47	21	17	9
[illegible]	47	27	13	11
[illegible]	47	21	17	10
[illegible]	59	29	21	10

Table 4 - 2
Sht 2 of 6

Standards & Parameters / Criteria & Weighting	Points	A. Technical Feasibility	B. Economic Potential	C. Industry Acceptance
		40	40	20
MAJOR COMPONENT / SUB-SYSTEM				
[illegible] SYS. DESIGN'S [illegible]				
SYS. DWGS. APPVD.	64	25	26	13
SYS. SPECS.	57	23	21	13
COMPONENT / COMPONENTS				
[illegible]:				
HEAT TRANSFER	46	25	21	9 (11)
FEED [illegible]	57	37	33	17
FLUE GAS COND.	61	25	25	11
[illegible] TO BOILER	75	35	26	14
ARR. & SIZE - FEED [illegible]	75	37	27	11 (9)
ARR. & SIZE - FLUE GAS IN & OUT	73	35	27	11 (9)
[illegible] SIZE & WT.	66	37	18	11 (9)
SHIP'D ASSEMBLED [illegible]	73	30	26	17
SPECS	62	27	23	12 (11)
APPVD. MATL. DWGS.	65	25	24	11
AIR PRE-HEATER:				
CAPACITY	80	37	37	11
HEAT TRANSFER	69	25	29	11
AIR IN & OUT [illegible]	75	35	27	13
[illegible] STEAM [illegible]	64	37	23	9
[illegible] SIZE & WT.	71	39	19	13 (9)
ARR. & SIZE AIR	77	38	27	12 (9)
ARR. & SIZE FLUE GAS [illegible]	75	35	27	13 (9)
CONTROLS	66	29	26	12
ON BOILER	76	33	29	15
SPECS.	70	31	25	14 (11)
APPVD. MATL. DWGS.	67	25	29	13
FORCED DRAFT BLOWER:				
[illegible]	41	20	17	4 (11)
RPM	84	39	29	16
STATIC EFFICIENCY	59	33	21	6 (11)
AIR FOR [illegible]	69	35	25	9 (11)
RPM	65	19	18	9
BHP	65	29	24	13
PRESSURE	84	32	30	13
BLOWER TYPE	77	32	36	14
DRIVE [illegible]	59	31	17	12
CONTROLS	66	36	20	10
[illegible] SIZE & WT.	69	47	21	11 (9)
ARR. & SIZE OF [illegible]	67	27	30	10 (9)
SHIPPED ASSEMBLED	75	39	31	15
SPECS.	71	37	22	12 (11)
APPVD. MATL. DWGS.	62	25	26	11
BOILER CONTROLS:				
[illegible]	70	32	29	10
SENSITIVITY	66	36	20	10
RESPONSIVENESS	66	36	20	10
[illegible], ELECTRONIC	53	38	10	5
[illegible]	56	38	10	8
[illegible]	56	38	10	8
[illegible]	56	38	10	8
[illegible]	56	38	10	8
[illegible]	56	38	10	8
WATER LEVEL CONTROL	56	38	10	8
[illegible] CONTROL	56	38	10	8
[illegible]	51	38	9	5
[illegible]	51	38	9	5
[illegible]	44	32	9	4
SPECS	60	34	20	6
DWGS.	61	36	20	5
[illegible] MANUALS	53	38	10	5
AUX PARTS - BOILER:				
[illegible]	50	29	21	6 (11)
[illegible]	45	19	21	5
[illegible]	52	28	21	3
MATERIAL SPECS	55	29	21	6
DWGS	51	27	26	6
AUX PARTS - [illegible]: SAME COMMENTS AS BOILER PARTS		SEE COMMENTS FOR AUX PARTS - BOILER		
AUX PARTS - [illegible]: SAME COMMENTS AS BOILER PARTS				
AUX PARTS - [illegible]: SAME COMMENTS AS BOILER PARTS				
AUX PARTS - [illegible]: SAME COMMENTS AS BOILER PARTS				
AUX PARTS - FEED [illegible]: SAME COMMENTS AS BOILER PARTS				
AUX PARTS - FEED PUMPS: SAME COMMENTS AS BOILER PARTS				
L.B. [illegible]:				
[illegible]	46	27	23	5 (11)
[illegible]	42	23	13	6 (9)
[illegible]	50	27	17	6 (11)
TYPE L.B. [illegible]	76	37	25	14
L.B. [illegible]	62	33	17	12
CAPACITY	76	37	27	12
[illegible]	60	27	21	12
[illegible] & BOLTING	47	22	17	8

Standards & Parameters / Criteria & Weighting	Points	A. Technical Feasibility	B. Economic Potential	C. Industry Acceptance
		40	40	20
COMPONENT / COMPONENTS				
L.B. CHILLERS (CONT.):				
[illegible] SIZE & WT.	69	37	22	10 (9)
ARR. & SIZE [illegible]	63	29	22	12 (9)
ARR. & SIZE [illegible]	63	29	22	12 (9)
[illegible]	63	31 (11)	17	15
[illegible]	73	32	27	11
ARR. & OP SPECS	60	25	23	12 (11)
APPVD. DWGS	61	25	25	11
[illegible] MANUAL	66	29	25	12
L.B. SERVICE PUMP:				
[illegible] CAPACITY	73	37	25	11
[illegible] PRESSURE	79	36	29	14
EFFICIENCY	50	27	18	5 (11)
HP [illegible]	70	33	25	12
RPM	63	26	25	12
[illegible]	70	37	29	14
MATERIAL	50	22	21	7 (11)
[illegible]	45	19	17	9
PUMP TYPE	75	45	25	15
[illegible] SIZE & WT.	70	37	21	12 (9)
[illegible] SIZE & WT.	71	32	26	13 (9)
[illegible]	74	33	29	12
[illegible] ON L.B. [illegible]	71	35 (11)	23	13
ARR. & OP SPECS.	69	29	27	12 (11)
APPVD. MATL. DWGS.	68	28	29	11
[illegible] MANUAL	75	29	33	13
L.B. STRAINERS:				
CAPACITY	73	36	26	11
PRESSURE DROP	59	26	23	10
TYPE - DUPLEX	69	30	23	15
[illegible] MESH	49	28	16	5
MATERIAL	54	27	19	8 (11)
[illegible] SIZE & WT.	63	33	17	13 (9)
[illegible] SIZE & [illegible]	57	25	20	13 (9)
[illegible]	61	29	23	9
MOUNTED ON L.B. [illegible]	77	35 (11)	29	13
ARR. SPECS.	56	27	21	8 (11)
APPVD. MATL. DWGS.	64	29	24	11
[illegible] MANUAL	57	22	24	12
L.B. HEATERS:				
[illegible]	58	25	21	4 (11)
CAPACITY	66	30	25	11
[illegible] TUBES	46	26	23	5
TYPE	69	30	24	14
[illegible]	57	29	17	11
[illegible]	63	29	21	13
[illegible]	56	30	16	10 (9)
ARR. & SIZE [illegible]	56	26	19	11 (9)
[illegible]	57	29	19	11 (9)
[illegible] & BOLTING	46	22	17	7
L.B. [illegible] SYS. [illegible]	77	37 (11)	29	11
APPVD. MATL. DWGS.	61	27	24	10
SPECS.	59	27	21	11 (11)
[illegible] MANUAL	66	29	24	11
L.B. [illegible]:				
CAPACITY	75	37	26	12
[illegible] OF L.B.	68	33	26	9
[illegible]	58	29	20	9
RPM	67	31	25	11
TYPE - [illegible]	77	37	25	15
[illegible]	70	30	25	15
[illegible] SIZE & WT.	70	37	22	11 (9)
ARR. & SIZE - L.B. [illegible]	70	33	25	12 (9)
ARR. & SIZE OF [illegible]	69	33	25	11 (9)
ARR. & SIZE [illegible]	75	37 (11)	27	11
[illegible] & BOLTING	57	25	19	8
L.B. [illegible] SYS. MANUALS	91	37 (11)	41	13
APPVD. MATL. DWGS.	57	22	25	11
SPECS.	63	29	22	12 (11)
[illegible] MANUALS	59	22	25	12
L.B. SERVICE PUMPS:				
[illegible] CAPACITY	57	25	21	11
[illegible] PRESSURE	57	24	21	12
EFFICIENCY	40	21	16	3 (11)
RPM	54	21	24	8
TYPE	63	29	24	11
[illegible]	66	29	24	14
POWER REQUIRED	57	24	25	13
[illegible] SIZE & WT.	55	28	17	10
[illegible]	44	19	20	5
[illegible] & BOLTING	44	20	17	7
L.B. [illegible] SYS. MANUALS	62	27 (11)	24	11
APPVD. MATL. DWGS.	58	28	24	10
SPECS.	56	24	21	11 (11)
[illegible] MANUALS	55	20	24	11
[illegible] SERVICE PUMPS:				
[illegible] CAPACITY	79	39	29	12
[illegible] PRESSURE	79	38	29	14
EFFICIENCY	47	27	17	4 (11)
RPM	64	28	21	10
TYPE	84	37	33	14
[illegible]	84	39	29	16
POWER REQUIRED	73	35	25	13
[illegible] SIZE & WT.	75	39	24	12 (9)
[illegible]	72	34	25	13 (9)
[illegible] & BOLTING	60	29	23	7
L.B. SERVICE SYS. MANUALS	84	39 (11)	32	13
APPVD. MATL. DWGS.	73	29	32	12

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PARAMETERS	Totals	A. [illegible]	B. Economic Potential	C. [illegible] Acceptance	
		48	40	20	
Equipment/Components					
[illegible]:					
SPECS.	63	31	25	12	[illegible]
[illegible]	63	29	23	11	
[illegible]:					
CAPACITY	63	32	26	12	
[illegible]	55	25	25	5	[illegible]
[illegible]	42	21	15	6	[illegible]
[illegible]	64	33	19	12	
[illegible]	65	33	23	13	
[illegible]	60	36	23	11	
TYPE	78	37	26	15	
MATERIALS	56	26	23	7	[illegible]
[illegible]	49	22	19	7	
MOUNTING SIZE & WT	70	37	22	11	(9)
[illegible]	66	26	27	12	(9)
[illegible]	60	26	22	12	(9)
[illegible]	60	26	22	12	(9)
[illegible] SYS. [illegible]	56	39 (7)	23	12	
SPECS.	68	33	23	12	[illegible]
[illegible]	59	22	26	11	
[illegible]	60	22	26	12	
[illegible]:					
CAPACITY	67	30	25	12	
PRESSURE DROP	61	27	15	9	
[illegible]	70	30	25	15	
[illegible]	53	27	19	7	
MATERIALS	57	25	22	10	
MOUNTING SIZE & WT	60	32	17	11	(9)
[illegible]	60	26	22	12	(9)
[illegible]	67	29	27	11	
[illegible]	73	32 (7)	29	13	
[illegible]	59	32	16	11	
SPECS.	61	26	23	12	[illegible]
[illegible]	60	22	26	12	
[illegible]:					
[illegible]	53	23	23	7	(11)
[illegible]	50	21	23	6	(11)
[illegible]	56	27	25	4	(8)
[illegible] SPECS.	52	22	23	7	(11)
[illegible]	52	20	27	5	
[illegible]:					
[illegible]	34	32	0	2	
[illegible]	32	30	0	2	
[illegible]	55	40	0	15	
[illegible] - PNEUMATIC HYDRAULIC ELECTRIC MECHANICAL	74	28	34	12	
[illegible]	24	24	0	0	
[illegible]	49	28	16	5	
[illegible]	54	26	24	10	
[illegible]	73	36	20	17	
MOUNTING SIZE & WT	56	26	20	10	
[illegible]	60	24	26	10	
SPECS	55	12	36	7	
[illegible]	46	10	36	0	
[illegible]	44	8	36	0	
[illegible]:					
[illegible]	35	32	0	3	
[illegible]	34	32	0	2	
[illegible]	45	40	0	5	
[illegible] - PNEUMATIC HYDRAULIC ELECTRIC	66	36	16	14	
[illegible]	16	16	0	0	
[illegible]	50	32	12	7	
[illegible]	60	24	26	12	
[illegible]	61	38	6	17	
MOUNTING SIZE & WT	56	26	20	10	
[illegible]	72	32	30	10	
SPECS.	59	16	36	7	
[illegible]	49	12	36	0	
[illegible]	46	10	36	0	
[illegible]:					
[illegible]	58	30	16	12	
[illegible]	62	28	26	14	
[illegible]	50	24	16	10	
[illegible]	62	32	20	10	
[illegible]	36	8	20	8	
[illegible]	54	24	20	10	
[illegible]	36	14	12	10	
MOUNTING SIZE & WT	37	16	16	5	
[illegible]	60	26	24	10	
SPECS	59	16	36	7	
[illegible]	44	8	36	0	
[illegible]	40	4	36	0	
[illegible]:					
[illegible]	52	27	21	4	[illegible]
[illegible] SPECS	51	22	22	7	[illegible]
[illegible]	53	22	26	5	
[illegible]:					
[illegible]	53	27	21	5	[illegible]
[illegible] SPECS	51	22	22	7	[illegible]
[illegible]	53	22	26	5	
[illegible] & MATERIALS					
[illegible]	65	29	23	13	[illegible]
[illegible] SPECS.	62	26	23	13	[illegible]

Table 4 - 2
Sht 4 of 6

NOTES TO EVALUATION MATRIX:

1. The propulsion plant RPM is difficult *to* standardize but not impossible. It can be-standardized for the same class vessels .at the same speed. Since most main turbines turn at approximately the same speed, the required porpeller pitch and the number or reductions accomplished by the reduction gear developing a specified shaft horsepower. *In* general the shaft RPM is determined by the hull requirements and ships' operational profile.

2. Fuel rates of any two steam turbine plants of the same power range but of different manufacturers may not be equal. However, the differences are generally small, when comparing equal propulsion plants. The auxiliary equipment in different types of ships of equal 'horsepwer have more effect upon fuel rates than a change in main turbine manufacturer.

3. From discussion with various turbine and boiler manufacturer, it has become apparent that standardizing the superheated steam conditions is not only acceptable and desirable, but is almost universally accomplished to date.

4. The number of boilers in the steam Drowlsion Dlant received a lower rating in economic potential because this standard parameter will have little effect on decreasing the costs of shipbuilding. However, the number of boilers does have some economic potential since it i.s a necessary item within the standard for engine room arrangement. Reducing the number of boilers in a ship has good economic potential. However, this fact is not dependent upon the standards program.

5. The Navy has standardized this item in preliminary design for a class of vessels. The merchant fleet might be able to accomplish the same. However, changes in vessel speed and therefore, RPM and shaft size will necessitate changes in the reduction ratio and possibly the arrangement of reduction gears and shafting, thereby making standardization of engine room arrangements difficult. It should also be noted that the horsepwer standardization may be more universally applied when the shaft RPM is flexible thereby making the standardization of reduction gear technically feasible.

6. Technically feasible only if the engine room arrangement becomes standardized.

7. Even though the heat balance is considered suitable for standardization, the losses and efficiency of the steam, condensate and feedwater systems will vary.

8. The *use* of standard preformed pipe and the establishment of standard piping interfaces is technically feasible only if the engine room arrangement and the envelope or module concepts are adopted for standardization.

Table 4 - 2
Sht 5 of 6

9. This item requires the development of an envelope around the equipment to define the piping, foundation and interface locations thus allowing all manufacturers to be capable of connecting to the appropriate locations. The manufacturers will not accept the location of Piping interfaces such that they would be required to change their present marketing designs. In addition, size and weight parameters *must* be based on the maximum normal.

10. This item requires a standard location for the fireroom bulkhead; thereby requiring the adoption of the standard engine room envelope.

11. Manufacturers would feel this cuts into their competitive position.

12. The boiler envelope, establishing interface locations, is technically sound and acceptable to the manufactruers surveyed with this word of caution:

    The location of interfaces on the imaginary envelope should be such that one manufacturer does not have to provide more piping than another due to the high cost of high pressure and ternpeiature piping. in addition,the piping and support system must be of sufficient strength and stiffness to act as an anchor point in the piping stress analysis.

13. Standardization of approved boiler installation drawings and technical manuals cannot be independently evaluated fortechnica1 feasibility and economic potential. They are interrelated.

14. This item is too difficult to use the envelope concept in locating interfaces.

15. The number of locations of piping interface points vary per manufacturer.

16. This item must be standardized only as to the maximum and minimum temperatures of the inlet water and the minimum temperature rise allowable in this range.

17. Shipping weight and shipyard facility crane capacities may cause difficulties to the establishment of national standards.

18. Module design should be such that it does not eliminate any viable manufacturer as an eligible vendor.

19. Consider these as procurement and/or general specs. Cresting standard specs which would cause a change in manufacturer's design would be unacceptable.

20. These should be recommended standards not hard specifications except as required by the ABS and the U.S. Coast" Guard requirements.

Table 4 - 2
Sht 6 of 6

The total package level, Group 1, consists of standards parameters which can be utilized to define and design the total propulsion plant. Table *4-3* is the Group I listing for the steam propulsion plant.

The Systems/Equipment Modules form Group II. The primary types of standands for each module would be *its* interface and packaging; the supporting types of standards would be the performance and operation of the module as a system as well as its component equipment where applicable. The nmdules are found at two levels -- Major Equipment/Sub-System and Equipment/Component. Table 4-4 is the Group II listing for the steam propulsion plant.

Similar logic was used to develop Group Ill, Equipment Envelopes and Group IV, Individual Equipment/Components. Tables 4-5 and 4-6 are the Group Ill and IV listings for the steam propulsion plant.

4.1.3.1 GROUP I - TOTAL PROPULSION PIANTS

This group of standards candidates consists of the three basic types of propulsion plants, steam, diesel and gas turbine, subdivided in comnon horsepower ranges as listed in paragraph 4.1.1.

Within this group the equipment and machinery which collectively formed a standard propulsion plant are defined for each horsepower range. Each horsepower range contains standards for major components as to their performance, type, description, operating characteristics, size (maximum) and weight (maximum]. The following standard ranges are covered:

Steam Turbine Plants	15 - 17,500 SHP
	24 - 26,000 SHP
	28,400 - 32,000 SHP
	36 - 40,000 SHP
	43 - 45,000 SHP
	50,000 SHP

LEVEL	TYPE OF ST'D	STANDARDS PARAMETERS FOR STEAM PROPULSION PLANTS AND ALL APPLICABLE EQUIP & SYS
A	1	SHP
ABCD	2	Steam Conditions
ABCD	2	Condensate Conditions
ABC	2	Heating Stages
A C	2	No. of Boilers
A	5	Heat Balance
ABCD	5	Technical Sepcifications
ABCD	5	Coast Guard Approvals
ABCD	5	System Drawings
ABCD	5	Calculations
ABCD	2	Feed Conditions
ABCD	1,2	HP of Major Equipment
ABCD	1	Capacity of Major Equipment
C	2	Generating Surface of Condenser
A C	2	Cycle Type (Reheat-Non-Reheat
ABCD	2	Type of Major Equipment
ABCD	3	Controls (Automation)

TABLE 4-3 GROUP I STANDARDS - TOTAL STEAM PROPULSION PLANT

KEY:
A = Total Package
B = Major Sys.
C = Major Equip/Sub-Sys.
D + Equip./Components

1 = Performance
2 = Operation
3 = Interface
4 = Packaging
5 = Software

LEVEL	TYPE OF ST'D		STANDARD PARAMETERS	EQUIPMENT/ SYSTEM	RELATIVE RANK
	MAJOR	SUPPORT			
C,D	3,4	1,2,5	Condensate Pump Module	Condensate Pumps	1
C,D	3,4	1,2,5	Main Feed Pump Module	Mn Feed Pumps In-Port Feed Pumps	2
C,D	3,4	1,2,5	F.O. Service System Module	F.O. Services Sys. F.O. Sew. Pumps F.O. Strainers F.O. Heaters	3
C,D	3,4	1,2,5	High Pressure Feed Heater Module	3rd Stage Htr. 4th Stage Htr.	4
A	3	5	Structural Modules	Struct. Modules	5
C,D	3	1,2,5	Power Unit Module	Main Turbine Condenser Air Ejector	5
C,D	3,4	1,2,5	L.O. Purifying Module	L.O. Purifier L.O. Heater L.O. Pur. Pumps	6
C,D	3,4	1,2,5	L.O. Service Sys. Mod.	L.O. Coolers L.O. Strainers L.O. Pumps	7
C,D	3,4	1,2,5	L.P. Feed Heater Mod.	1st Stage Htr. Gland Leak-Off Cond. ADT 2nd Stage Htr.	8

TABLE 4-4 GROUP II STANDARDS, STEAM SYSTEMS/EQUIPMENT MODULES

LEVEL	TYPE OF ST'D		STANDARD PARAMETERS	EQUIPMENT/ SYSTEM	RELATIVE RANK
	MAJOR	SUPPORT			
C,D	3	1,2,5	Limiting Size & Weight	Boiler	1
C,D	3	1,2,5	Location and Size of Piping	Condensate Pumps	2
C,D	3	1,2,5	Piping to Interface Loc.	Main Turbines	3
				Air Preheater	4
				Economizer	5
				Main Circulation P.	6
				F.O. Service Pumps	7
				Bridge Controls	8
				L.O. Purifier	9
				Air Ejector	10
				Reduction Gears	11
				L.O. Service Pumps	12
				F.O. Heaters	13
				L.P. Feed Htrs.	

TABLE 4-5 GROUP III STANDARDS, STEAM EQUIPMENT ENVELOPES

LEVEL	TYPE OF ST'D	STANDARD PARAMETERS	EQUIPMENT/ SYSTEM	RELATIVE RANK
C,D	2	Environmental Requirements	Boilers	1
C,D	5	Approved Installation Dwgs.	Main F. Pumps	2
C,D	5	Technical Manuals	Condensate Pumps	3
C,D	3	Mounting Interfaces	Main Turbines	4
C,D	1	Reliability & Maintainability	Condenser	5
C,D	5	Specifications	L.O.Serv. Pumps	6
C,D	4	Shipped Ready for Assembly	L.P. Heaters	7
C,D	4	Shipped Assembled	Economizer	8
C,D	5	Calculations	Air Pre-heater	9
C,D	4	Packing & Protection	F.O. Service Pumps	10
C,D	2	Coupling Method	Engine Room Controls	11
C,D	2	Controls	Control Systems	12
			Reduction Gears	13
			Aux. Turbines	14
			Forced Draft Blowers	15
			Boiler Controls	16
			Thrust Bearing	17
			Air Ejector	18

TABLE 4-6 GROUP IV STANDARDS, STEAM INDIVIDUAL EQUIPMENT/COMPONENTS

Diesel Engine Plants	8 - 10,000 SHP
	12 - 14,000 SHP (2 Eng/Shaft)
Gas Turbine Plants	8 - 12,500 HP Heavy Duty
	15 - 20,000 HP Heavy Duty
	20 - 25,000 HP Aircraft Type
	30,000 HP Aircraft Type
	35 - 40,000 HP Aircraft Type
	45 - 60,000 HP Heavy Duty

In addition to defining the preliminary design type characteristics if the total propulsion plant, this group also keys the standard to lower level standards of greater detail. Therefore, the Group I standard is a top level reference document.

4.1.3.1.1 Standard Steam Turbine Propulsion Plant

The following are standards parameters at the total package level for the steam turbine propulsion plant: SHP, Fuel Range, Steam Conditions, Condensate Conditions, Heating Stages, Number of Boilers, Heat Balance, Technical Specifications, System Drawings, Calculations and Coast Guard Approvals.

The standard total plant concept consists of definitive standards parameters for the major equipment such as Boilers, Turbines, Condenser, Reduction Gear, Control System, Lubricating Oil System, Forced Draft Fans, Main Feed Pumps, Fuel Oil Service System, Circulating Water Pumps, Condensate Pumps and Feed Heating Systems. The necessary auxiliaries, although not part of this study, must be defined in order to size the main components of the plant.

4.1.3.1.2 Standard Diesel Plants

The standard total plant concept consists of definitive standards parameters for themajor equipment such as the Main Engines, Controls, Starting .System, Exhaust System, Fresh Water System, Lubricating Oil System, Fuel Oil System, Raw Water System and Reduction Gear.

4.1.3.1.3 Standard Gas Turbine Plants

Gas Turbine Plants have been essentially standardized at the total package level in that the available plant sizes are limited. . That is, each manufacturer markets a particular size (horsepower) gas turbine by type of which there is no competitive design, so that selection of the supplier is based solely on the design horsepower and type of turbine (Aircraft Derivative or Heavy Duty Industrial type).

There is a critical need *to* develop standards to suit the marine industry for the performance, design and purchase of gas turbines propulsion plants. However, it is deemed premature to attempt an economic analysis measuring the gains due to these standards since there is only one commercial installation to date in the U.S. to compare with.

4.1.3.2 GROUP II - EQUIPMENT/SYSTEM MODULES

This group of standards candidates consists of modules of like equipment or systems of equipment mounted together on one (or several) structural foundation (skid). Included are interconnecting piping, valves, fittings, electrical connections and controls. The standard module is defined by limiting dimensions and weights, foundation, interface and mounting locations and interfacing piping and electrical connections. The likely advantages include reduced installation costs, superior warranty, reduced test and checkout time an increased inter-; changeability of equipment sources.

The equipment/systems which lend themselves to being packaged together on skids are:

* F.O. Service System
* L.O. Service System
* L.O. Purifying System
* Power Unit
* H.P. Heaters Module
* Feed Pump Module
* First Stage Heater Module
* Condensate Pump Module
* Diesel Accessory Racks
* Diesel Starting Package

Local "Automation System" stations can also be packaged together as a module.

4.1.3.3 GROUP III EQUIPMENT ENVELOPES

This group of standards of an imaginary envelope with limiting dimensions and weight and including locations and sizes of interface connections. This is similar to the GROUP il Modules concept, except that the standard contains an individual component rather than a group of components. The main advantage is that the equipment becomes standard without influencing existing individual designs.

Most equipment in the propulsion power plant can be considered applicable. Boilers, turbines, condnesers, main feed pumps, heaters, coolers, condensate pumps, circulating pumps, purifiers, controls, air ejectors, diesel engines, fuel pumps lube oil pumps, strainers, filters and foundations. However, due to space limitations and the need to use space efficiently, extensive use-of envelope standards may be precluded. It seems likely that smaller components for which there is little space limitation will be suitable for enveloping.

In addition to these interface type standards, much of the equipment standards in GROUPS II and III may include operational characteristic and performance type standards Parameters which are applicable. For example, the following standards parameters apply:

1st Stage Heater:
- Capacity
- Steam Conditions
- Condensate Conditions

Steam System:
- Steam Conditions

Boilers:
- Capacity
- Fuel Rate
- Superheater Steam Conditions
- Feed Conditions

Main Turbines:
- HP
- Steam Conditions

Condensate Pump:
- GPM
- Rated Head
- RPM
- Type

4.1.3.4 GROUP IV- INDIVIDUAL EQUIPMENT/COMPONENTS

The standards which are applicable to most of the propulsion plant equipment include items such as "shipped assembled", "protection and packaging", "controls", "procurement specifications", **"general specifications** "approved installation drawings", "mounting interfaces", "calculations" and "technical manuals". These items are flexible and general enough to allow industry acceptance, however, they are of questionable value to the industry. The parameters which were considered such as materials, reliability, durability, heat transfer coefficient, and other design specifications received low grades when the selection criteria was applied due to poor industry acceptance.

In spite of these facts, as the standards feasibility. study matured, a consensus of opinion has been reached that if GROUP IV standards could be. implemented, they would most certainly provide savings in shipbuilding costs. There is a big dollar saving potential in this group of standards.

To provide a step-by-step approach to complete standardization, the following stages of standards development were adopted:

a) Data Standard: includes all technical information at the vendor plant level of detail, in a standard format. This standard would enable the shipyard to incorporate the subject component into the ship design but it would exclude all sales documentation.

b) Procurement Standard: is an intermediate step of the standardization where all of the performance and operating characteristics and some of the physical characteristics are standardized. Procurement documents covering both technical and legal data are prepared in standard formats.

c) Hardware Standard: is the final stage of standardization where the component in question is completely standardized and as such becomes an "off-the-shelf" item.

Practically all components comprising a ship's propulsion plant may be candidates for GROUP IV standardization. However, for the purpose of this study, only three will be considered and economic analyses will be performed *on* these three components for the three different kinds of standards.

4.1.4 CONCLUSIONS AND RECOMMENDATIONS

Results of the investigation and selection of standards candidates indicates that implementation of a standards program for U.S. shipbuilding is technically sound, has the prospects of being acceptable to the industry and shows good potential for achieving appreciable *costs* savings in shipbuilding.

However, careful evaluation and consideration should be given to-the selection of standards to be implemented and the priority assigned. Industry acceptance is imperative for successful implementation of the standards.

The most significant reservations to the standards program which reflect the posture of industry include the following:

1. The marine market is a small percentage of total sales and therefore will have little influence in instituting changes.
2. Difference in ship designs and shipyard facility capabilities make national standards difficult.
3. Some shipyards already use a modified form of shipyard standard.
4. Equipment manufacturers generally use standard product lines and would resist standards which force modification of their designs.

It was recommended that economic analysis be perfomred for a sampling of the standards. The selection of standards for economic analysis was based on the relative importance of the potential savings to be expected from each group of standards. Upon consideration of all results achieved so far and a re-evaluation of the over-all feasibility study, it was decided to assign the following priorities to the economic analyses:

1. Top priority would be given to the GROUP IV "Individual Equipment"standards and-effort would be spent to analyze economically the following three components for each kind of standards (i.e. the data, the procurement, and the hardware standards):

   a) Main Condensate Pump (for a 26,000 SHP Steam Turbine

Propulsion Plant)

b) Starting Air Compressor (for a 14,000 SHP Medium Speed Diesel Propulsion Plant)

c) Main Boiler (for a 26,000 SHP Steam Turbine Propulsion Plant)

2. The next level of priority would be assigned to the GROUP "Total Plant Standards" and effort would be spent for economically analyzing the following two total plant standards:

   a) 26,000 SHP Geared Steam Turbine "Propulsion Plant.

   b) 14,000 SHP Geared Medium Speed Diesel Propulsion Plant

3. GROUP 11 "Systems/Equipment Module" standards would receive the third level of priority and effort would be spent for the economic analysis of the foliowing three modules:

   a) Fuel Oil Service System Module for a 26:000 SHP Steam Turbine Plant

   b) Main Feed Pump Module for a 26,000 SHP Steam Turbine Plant

   c) Diesel Accessory Rack for a 14,000 SHP Medium Speed Diesel Plant.

4. The last priority would be given to the GROUP Ill "Equipment Envelope Standards" and effort would be used for the economic analyses of:

   a) Boiler Envelope

   b) L.O. Purifier Envelope

   c) Main Circulating Pump Envelope

   all of which are for a *26,000 SHP* Geared Steam Turbine Propulsion Plant.

4.2 GENERAL

4.2.1 Purpose

The broad objective is to study the feasibility of developing standard's for utilization on U.S. commercial ship propulsion plant equipment which would result in reducing the time and cost of building ships. The propulsion plant systems under consideration are for ships of 10,000 DWT capacity and over which are to be contracted through 1985. At present,. the use of industry-wide propulsion plant standards is nearly non-existent. The heart of the problem is to uncover profitable aspects for standards utilization and then to convince the builder/manufacturer/owner that they will, indeed, benefit. Putting it another way, the broad objective of the project is to find common grounds within the propulsion plant framework for teamwork between competing firms to solve industry-wide problems and improve shipbuilding efficiency. This task is a difficult one, since the rival firms are not used *to* working together towards common goals. The specific objective of this task of the feasibility study is to perform technical analyses of propulsion plants and to determine the candidates for which standards may be written.

In approaching this, one must remain careful that establishment of standards will not stifle competition and individual incentive. Also, one must insure that the use of standards which might result in reducing the cost of the ship will not adversely influence the cost of ship operation.

The task of the selection of systems/subsystems standards candidates is considered crucial, since it sets the direction for the whole study. It includes the development of the criteria for selection of standards parameters, evaluation of the forecasts and determination of the components to be covered by standards and finally adopting the type and level of standards. For a detailed description of the definition of "Standards," please refer to 4.4.3.

Specifically, this Task consists of a technical evaluation of the propulsion plants which reflect the requirements of the ships forecast to be ordered in U.S. Shipyards to 1986. A primary result of this Task will be the selection of viable standards candidates for further economic analysis.

4.2.2 Approach

The plan utilized in implementation of this Task consisted of gathering data and information regarding propulsion plant standards and applying this data to develop a practical application of standards utilization to the commercial marine shipbuilding industry.

The necessary research included a literature search of technical publications, papers, and trade magazines. A list of pertinent documents, bibliography, is included in Appendix B.5.

Various members of the marine industry were contacted to provide their initial viewpoint and contribution as to which aspects of propulsion plants they would prefer to see standards developed for. Shipbuilders, ship owners, ship operators, and equipment manufacturers were visited and opinions regarding standards were exchanged. Recurring problems were discussed. Table 4-7 represents companies which were contacted for consultations. Minutes of a sample of the consultation meetings is included in Appendix B.4.d. Trip reports of visits to some shipyards are included in Appendix B.4.a and B.4.b.

Foreign shipbuilding industry representatives were contacted. Information was gathered from which a determination could be made on the values placed on propulsion standards in foreign countries and the possible applicability to U.S. shipbuilding. Minutes of the meetings with the Greek ship-ping industry representatives are included in Appendix B.4.c.

Research was conducted concerning standards utilized in other industries such as the oil drilling, industrial power plant, building, automotive, and shipping industries. Applicability of standards to shipbuilding was. investigated.

Information gathered during the performance of Task 1, forecast, of this study was utilized. The forecast data was applied both in determination of which type of propulsion plants to emphasize and in detailed analysis of the propulsion equipment.

American President Lines, Ltd.
American Steamship Co.,
  Boland & Cornelius, Inc.
Andreadis Shipyards
Atlantic Richfield Co.
Avondale Shipyards, Inc.
Babcock & Wilcox Co.
Bailey Controls, Inc.
Bath Iron Works Corp.
Bethlehem Steel Corp.
Borg-Warner Corp.,
  Byron Jackson Pump Div.
Burmeister & Wain American Corp.
"Cherma" Electronics
Chevron Shipping Co.
Coffin Turbo Pumps,
  FMC Corp.
Colt Industries, Inc.
Combustion Engineering, Inc.
Competition, Inc.
Consolidated Controls Corp.
Curtis Wright Corp.
De Laval Turbine, Inc.
Drewry (HP) Shipping Consultants,
  Ltd.,
  Engineering Controls Div.
Empeirikos Shipping
Exxon Co., USA
Ifoster Wheeler Corp.
General Dynamics Corp.
  Quincy Shipbuilding Div.
General Electric Co.
General Motors, Inc., EMD
General Regulator Co.
Getty Oil Co.
Gould Pumps, Inc.
Graham Manufacturing Co.
Ingalls Shipbuilding,
  Div. of Litton Industries
Karageorgis M. Shipping
Kelso Harine, Inc.
Lakes Carriers Association
Livingston Shipbuilding Co.
Litton industries Marine Group
Lockheed Shipbuilding S Con-
  struction Co.
Lufkin Industries, Inc.
Lykes Bros. Steamship Co., Inc.
Marathon Manufacturing Co.
Marine Transport Lines, Inc.
Maritime Transport Research
Maryland Shipbuilding & Drydock Co.
Mobile Oil Corp
National Steel & Shipbuilding Co.
NAVSEA
NAVSEC
Newport News Shipbuilding &
  Drydock Co.
Niarchos Shipyards
Nissho-lwai American Corp.
N.J. Goulandris Shipping
Prudential Grace Lines, Inc.
Sea Land Services, Inc.
Seatrain Shipbuilding Corp.
Shell Oil Co.
Stal-Laval, Inc.
Sun Shipbuilding & Drydock Co.
Texaco Inc.
The Falk Corp.
The Terry Steam Turbine Co.
Todd Shipyards Corp.
Turbo-Dyne Corp.
Turbo Power & Marine Corp.
United Tanker Corp.,
  United Tanker, Ltd.
Warren Pump Co.
Waste Heat Engineering Co.
Western Gear,
  Heavy Machinery Div.
Westinghouse Electric Corp.
White Industrial Power, Inc.
  Alcoa Engines Div.
Worthington Turbine International
U.S. Coast Guard, Washington, D.C.

ORGANIZATIONS CONTACTED

TABLE 4-7

The results of the forecast specifically showed that:

1. The quantity of ships to be ordered from U. S. shipyards indicates that the shipbuilding industry will thrive during the next ten to fifteen years. The use of propulsion plant standards may help reduce the costs.
2. The emphasis in selecting standards for propulsion plants should be placed on steam turbines first and then on gas turbines and diesels.
3. The sizes of propulsion plants for investigation should be grouped as follows:

<u>Steam (239 Plants to 1985)</u>

15,000 - 17,500 SHP (13 plants)
24,000 - 26,000 SHP (76 plants)
28,500 - 32,000 SHP (27 plants)
36,000 - 40,000 SHP (92 plants)
43,000 - 45,000 SHP (20 plants)
50,000 - SHP (11 plants)

<u>Diesel (90 Plants to 1985)</u>

7,000 HP (26 plants)
14,000 HP (50 plants)
28,000 HP (14 plants)

Gas Turbine (119 Plants to 1985)

12,500	HP	(32 plants)
25,000	HP	(11 plants)
30,000	HP	(39 plants)
35,000	HP	(16 plants)
40,000	HP	(8 plants)
60,000	HP	(13 plants)

4.3 STANDARDS PAST AND PRESENT

4.3.1 HISTORY

In general national standards utilized today in U.S. commercial shipbuilding are nearly non-existent. During World War II, standard designs were utilized freely. But this was born of necessity. One boiler design was used and all major suppliers manufactured the same boiler. The same applied to much of the equipment used in shipbuilding. However, competition was not in jeopardy, since the demand was always greater than the supply. An important source requiring the use of standard machinery designs was the large quantity of ships of one design which were built in several shipyards, e.g. Liberty Ships and Victory Ships. The major problem which resulted in discontinuing the use of standards was the shortage of materials.

The lesson to be learned from the past is that standards have been used effectively and that, evidently, there was a need which they fulfilled.

4.3.2 PRESENT PRACTICE

A majority of propulsion machinery manufacturers utilize their own company standards. In most cases, the requirements for these standards are dictated by industries other than the marine industry. In general, the marine market accounts for less than five per cent of the total sales of the machinery suppliers.

For this reason, the influence of the marine industry upon equipment suppliers is not strong.

The standards utilized by each manufacturer generally do not relate to those of his competitors. For example, H.P. turbines of each manufacturer are supplied in frame sizes which cover a range of horsepowers. L.P. turbines are supplied in frame sizes with ranges which overlap the H.P. ranges. A combination of H.P. and L.P. turbines can be supplied to cover the required ship's horsepower by combining different frame sizes. Each manufacturer *uses* different horsepower ranges for his frame sizes, resulting in noncompatibility of turbines among competitors.

National standards generally are utilized only in the lowest level of machinery components. Standards which are commonly used in shipbuilding include screw threads, pipe and tube sizes, fittings, valves, electric motor frames, wiring and junctions.

Materials for use in piping systems and equipment are not usually included in standards. However, there are recommended materials which are commonly used in particular systems and for particular applications. U.S. Coast Guard, American Bureau of Shipping and Maritime Administration each have regulations which set some material standards. Good marine engineering practice dictates many material type standards. Many problems encountered in purchasing and delivery schedule of equipment could be eliminated by the use of material standards. For example, if one particular material were standard for a given utilization (such as Copper Nickel pipe for salt water application), the equipment supplier could be set up for manufacture using that material for orders from different shipyards. Present common practice dictates that an order from one shipyard, with a different material from that of another, causes a delay until the equipment supplier can break into the manufacturing cycle to change materials.

It may be concluded from the foregoing that there is a need for material standards-and that these standards would not be difficult to write. However, shipyard design personnel and ship owners have expressed opposition to these standards. They wish to have complete freedom in material selection and fear that setting material standards would further increase delays in selection of non-standard materials.

4.3.3 STANDARDS UTILIZATION PRACTICES IN OTHER INDUSTRIES

A review of other industries to determine standards practices which may be. applicable to the marine propulsion industry has uncovered the following:

A. Aircraft and automotive industries show very limited utilization of national standards. Standards utilization is restricted to parts such as threads and bearings. Components and systems are standardized by individual manufactuer The large quantity of units mass produced in these industries allows savings by use of company standards. In the aircraft industry, when feasible, propulsion engines designed for one type aircraft are sometimes utilized on another type aircraft. The main purpose is to reduce development costs and time which are major items in that industry. However, competitive engine manufacturers make non-standard different engines for similar applications.

B. The off shore drilling industry offered some basis for comparison. Again, national standards utilization is limited to components similar to other industries. However, some industry standard practice is worth noting.

1. Modularization (skidmounted) of systems is common in the industry. Companies "specialize in packaging of these systems and market these to the entire industry. Some systems which are common modules include propulsion diesel generator *sets*, water pumping systems, etc.
2. Motors and pumps are standard size on a ship. For example, pumps for the mud system, drill water system, bilge system, ballast system, and circulating water system are all the same size. The quantity of pumps required for . each system is adjusted.

3. Owners Use fleet wide standards. That is, one manufacturer's product will be standard for all of the owner's fleet. This reduces costs in several ways. Purchasing costs, design costs, spare parts costs and maintenance costs are all reduced. Installation is facilitated by familiarity.

4. The entire industry uses commonly sized equipment when possible. This is a practical consideration rather than a published standard. For instance, 750 HP D.C. motors are commonly used throughout the industry to drive the drilling equipment as well as the ship's equipment.

c. The building industry uses standard madules in construction of multiple unit dwellings. However, the modules are usually standard within several manufacturers only. National standards are used only for components such as piping, fixtures, etc. Recent developments in the industry indicate that standard modules (such as entire bathroom module) may be realized in the near future. Problems which have developed which are parallel to those in the marine industry are packaging, handling and shipping of these modules. Sizes must be kept within shipping mode limitations and handling of the large modules at remote sites proves difficult.

4.3.4 EXPERIENCE OF FOREIGN SHIPBUILDING INDUSTRIES

The experience, in standardization, of the foreign shipbuilding industry is quite important to this study because of its relative position in the world market and its history of success. Representatives of the Japanese and European shipbuilding industries were interviewed to ascertain their views on standards/standardization of marine propulsion plants and current/future standards and automation practices. Admittedly, Japanese shipyards are in a much stronger position with respect to their national economy than U.S. shipyards are in the United States. In addition, U.S. shipyards could never attain this relative position because of the structure of the shipbuilding firms and their relation to the "Anti-Trust Laws." It is interesting to note the methods employed *in* Japan. Besides receiving a large amount of government support and owning/operating the *steel* industry and other related industries, the Japanese shipbuilders cooperate with each other. They have not lost the competitiveness between individual yards, but they deal in such a manner as to make themselves most Competitive with every shipbuilding industry in the world. For example, a council of Japanese shipbuilders met for the purpose of standardizing the size of super tankers up to a million tons and to determine the market for such tankers. They agreed to build only one size vessel and then each shipbuilder developed his own standard ship tailored to the capabilities of his individual facility.

A great deal of credit for the Japanese shipbuilding success is derived from the above mentioned form of cooperation between shipbuilders and the fact that they can use series production; but also important to their successful posture in the industry is the extensive degree of automated welding technique which they employ.

The structure of Japanese shipbuilding companies is such that company standards may be successfully employed. This parallels national standards. The ships are designed generally at a central office which is usually at corporate headquarters in Tokyo. These designs are then incorporated (ships built) at the several shipyards located at various points throughout Japan. The designs are only altered as required to accommodate the peculiarities of the facility of construction. Equipment is centrally procured. In addition, in the present market, ships are marketed by the shipbuilder with very little modification, so that the advantages of series production may be realized.

In review of some Japanese designs, one can note the packaging or modularization of equipment and systems. For instance, the fuel oil service system is packaged as a unit. (This is also accomplished by some of the successful U.S. shipyards and is being evaluated as a standard candidate in this study.)

The European shipbuilding representatives were less definitive in their response to questions, presented to them, on standardization. Some feel standardization would greatly reduce shipbuilding'costs, and are favorable towards the concept, but believe it to be a tremendously difficult task to accomplish due to resistance in the industry.

The European shipowners, which were surveyed, had a different view. They stated "as the situation stands today, shipowners can still command and receive quality and expediency from numerous , and competing shipyards." They feel that they might lose this position if standards are utilized for equipment, systems, or total propulsion plants.

There is some evidence of standards utilization in the European shipbuilding industry. However, again it is usually company oriented. Diesel engines are the most common propulsive prime mover. Of the 2900 ships carried in the world order books in January of 1974, 2500 were to have diesel propulsion. In the large tonnage ships (150,000 DWT and over), of 240 ships ordered only 20 *were* to be diesel driven. In the United Kingdom, diesel engine manufacturers utilize national standards. However, this is due to the uniting of the diesel engine corporations into one unit for economic expediency. The major diesel engine manufacturers in Europe do not use national or European standards. However, there is a tendency towards cooperation between competitors for common gain. For example, two major engine manufacturers combbined services to market one particular engine.

It is concluded that foreign shipbuilders generally do not use standards to any extent. There is a general feeling that the trend is to product lines or company standards. Series production of shipyard standard ships is the goal of most shipyards, but this is dependent upon the market.

4.4 PROPULSION PLANT ANALYSIS

4.4.1 CRITERIA FOR CANDIDATE EVALUATION

The criteria to be used in establishing a system, subsystem or component as a standard candidate were determined to be technical feasibility, economic potential and industry acceptance. These three basic criteria were weighted and contained additional detailed evaluation criteria as outlined below:

a. Technical Feasibility - Weight 40%

1. Technical soundness of establishing the candidate as a standard.
2. Potential for optimization of design.
3. Simplicity in manufacturing and installation procedures.
4. Correlation of the standards candidate to the other ship systems, especially those systems which will interface with the subject candidate.
5. Potential for the development of standards for the proposed candidates.

b. Economic Potential - Weight 40%

1. Potential for reduction in manufacturing costs, delivery time, installation costs and test and checkout time for the proposed candidate.

2. Possibility of establishing a practical application of the proposed candidate within the scheduled time frame.

c. Industry Acceptance - Weight 20%

1. Probability of acceptance of the proposed candidate as a standard by the shipbuilders.

2. Acceptance of the standards candidate by machinery/equipment manufacturers and/or suppliers.

3. Acceptance by the owners and/or operators.

4. Effect of establishing proposed candidate as a standard upon the competitive market. The effect must be such that it will not discourage innovation and competition.

The weights assigned each of the criteria above indicate the effect and contribution of that specific criterion upon the total acceptability of standardization for the system, subsystem, or the component equipment in question.

4.4.2 PLANT ANALYSIS

An evaluation of the forecast results determined the three basic propulsion plant categories as the steam, diesel, and gas turbine propulsion plants. Subdivision of systems, sub-systems and components for each of these propulsion plant categories was prepared and results tabulated in the form of a "Waterfall-chart." These charts for steam, diesel, and gas turbine propulsion plants are illustrated in figures 4-1, 4-2, and 4-3 respectively; and they show the propulsion plant segments which have been considered for the selection of standards parameters:

At total package level

At major systems level

At sub-systems level

At component/equipment level

The method used in formulating these charts was the use of the classical "textbook" approach to classify segments of a propulsion plant by basic fluid systems.

4.4.3 DEFINITION AND DESCRIPTION OF STANDARDS

The word "standard" is defined in the dictionaries as:

"Something which is established for use as a rule or basis for comparison in measuring or judging capacity, quantity, content, extent, value, quality, etc."

However, for the purposes of this feasibility study, the standard is defined as follows:

> STANDARD - "The formal written description of an item and/or procedure for the purpose of ensuring that some or all of the characteristics of said item and/or procedure are identical within specified tolerances of any other items and/or procedures conforming to said standard. The purpose of such conformation is to ensure compatibility, interchangeability, or other desirable features. One of the benefits of such features is a reduction in costs."

As such, the "standard" is a formal document which contains specific characteristics and/or conditions applicable to the equipment for which the standard is written. These various characteristics and conditions are labeled "standards parameters."

The "standards parameters" as applicable to this feasibility study are classified in accordance with their types and levels.

The type of a "standard" and/or "standards parameter" is identified as follows:

STANDARD TYPE - A given standard may be of one or more types. A type is a specific area of concern which, in addition to the level, defines the scope of a standard. Some of the types which will be used in this study are the following:

O	PERFORMANCE	SPEED, POWER, EFFICIENCY
O	CHARACTERISTIC CONDITIONS	INLET TEMPERATURE & PRESSURE, EXHAUST PRESSURE, VOLTS, AMPS, HERTZ
O	INTERFACE REQUIREMENTS	FOUNDATION TYPE & BOLTING, ENVELOPE SIZE & WEIGHT

O	PACKAGING	SHIPPING SIZE, PROTECTION, REQUIRED ROUTING, CARRIER
O	SOFTWARE	DRAWINGS, SPECIFICATION, PURCHASING

The level of a standard is identified as follows:

STANDARD LEVEL - The level specifies the degree of detail addressed by a standard. It can vary from individual components to total packages graded as follows:

O	TOTAL PACKAGE	PRIME MOVER THROUGH TRANSMISSION INCLUDING PROPULSION SUPPORT EQUIPMENT AND AUTOMATION
O	MAJOR SYSTEMS	STEAM SYSTEM, CONDENSATE SYSTEM, FEED SYSTEM
O	MAJOR EQUIPMENT/SUBSYSTEM	BOILERS, TURBINES, DIESEL ENGINE
O	EQUIPMENT/COMPONENT	PUMPS, HEATERS, MOTORS, PURIFIERS

Further classification of the levels, of course, is possible. However, for the purposes of this feasibility study, only the above four levels will be used.

An evaluation of the standards parameters was made for each of the types and levels established for various power plant categories in the waterfall chart individually. These are listed in the matrices, Tables 4-1, 4-8, and 4-9. The results became the lists of parameters to be evaluated: e.g., the steam propulsion plant's performance can be defined by stating its SHP, RPM, and fuel rate; its operating characteristics can be defined by stating the steam conditions, condensate conditions, heating stages, etc.

4.4.4 APPLICATION OF CRITERIA TO CANDIDATES

The criteria for selection of standards were applied to each of the parameters by using the numerical grading system for technical feasibility, economic potential and industry acceptance. (See tables 4-2 and 4-10) These criteria were weighted 40, 40 and 20 respectively, for a total of 100. The technical feasibility was weighted heavily since a candidate which is not technically feasible should not be standardized. Equally important is the degree of economic potential a candidate contains. A standards candidate must cause a significant cost savings or it cannot be considered for standardization, since preparing the "standard" will contribute to the cost. A candidate which was rated high in technical feasibility should be expected to be acceptable to the industry. However, in many cases, a candidate which is technically acceptable and has good economic potential may be considered by some segments of the industry to be partially or totally unacceptable due to requirements peculiar to that candidate or to the industry.

The candidates were graded individually by at least three experienced engineers, independently of each other, so that the results of one person's evaluation did not influence another's. In this manner, individual prejudices were minimized. The individual grades were then averaged and compiled on the grading

CRITERIA & MULTIPLIER / STANDARDS PARAMETERS & TOTALS		A. TECHNICAL FEASIBILITY	B. ECONOMIC POTENTIAL	C. INDUSTRY ACCEPTANCE
		40	40	20
TOTAL PACKAGE				
GAS TURBINE PROP PLANT:				
S.H.P.	78	39	21	18
VIBRATION ANALYSIS	79	37	27	15
R.P.M.	60	25	27	8
S.F.C.	59	27	25	7
NO OF UNITS	76	27	36	13
TYPE FUEL	66	33	26	7
TYPE POWER TRANS.	56	17	36	3
DUCT EFF.	77	37	25	15
ENG. RM. ENV.	59	26	25	8
ENG. RM. ARR.	64	27	29	8
SHAFTING ARR.	48	21	21	6
STABILITY CHRST.	45	15	21	9
DUCTING REQT.	66	26	29	11
STRUCTURAL/CUSTOM MISCELLANEOUS	70	30	31	9
STD. SPEC.	64	26	29	9
PRO. SPEC.	63	25	28	10
ABS/C.G. APPROVAL	66	19	33	14
STD. DWG.	69	27	34	8
ARR. DWG.	57	22	26	9
PIPING DWG.	67	21	33	13
INST. DWG.	69	25	33	11
CALCULATIONS	70	28	29	13
TECHNICAL MANUAL	78	29	33	16
MAJOR SYSTEMS				
GAS TURBINE MODULE:				
TYPE CYCLE	45	26	15	4
NO OF SHAFTS	59	23	27	9
RPM	58	30	19	9
INTAKE TEMP.	75	33	33	9
HUMIDITY	74	32	33	9
AIR FLOW	60	27	26	7
FIRING TEMP	48	26	17	5
PRESS RATE	59	25	29	5
EXHAUST TEMP.	48	30	13	5
TYPE FUEL	59	31	22	6
HEAT REJECTION RATE	48	27	16	5
SIZE	56	25	25	6
WEIGHT	56	25	25	6
PLATFORM INTERFACE	57	27	29	11
ASSEMBLED AS COMPLETED PKG.	79	37	27	15
PKG. SPECS.	64	31	24	9
ARR. DRWGS.	51	22	22	7
INST DRWGS.	71	31	31	9
TECHNICAL MANUAL	80	34	32	14
INLET/EXHAUST SYSTEMS:				
PRESSURE DROP	65	27	30	8
EFFICIENCY	56	24	21	11
MOISTURE REMOVAL	61	30	21	10
CAPACITY	69	34	27	8
NOISE CONTROL	61	30	22	[illegible]
DE-ICING ABILITY	62	22	26	12
REGENERATOR EFF.	53	26		
EXHAUST GAS TEMP. CONTROL	41	22	14	5
FLANGE LOCATION INLET/OUTLET	70	30	32	8
SIZE	72	33	29	10
WEIGHT	70	34	26	10
MODULARIZED	63	26	27	10
ABS/C.G. APPROVAL	61	18	29	14
ARRANGEMENT DWGS	57	18	32	7
INST. DWGS.	64	20	33	11
OPERATING MANUAL	65	27	24	14
AUXILIARY SUPPORT SYSTEMS:				
CAPACITY	67	30	27	10
EFFICIENCY/LOSSES	49	23	18	8
POWER CONSUMPTION	69	33	24	12
TEMPERATURE	43	25	15	3

CRITERIA & MULTIPLIER / STANDARDS CANDIDATES & TOTALS		A. TECHNICAL FEASIBILITY	B. ECONOMIC POTENTIAL	C. INDUSTRY ACCEPTANCE
		40	40	20
PRESSURE	52	27	18	7
TORQUE	59	31	21	7
SIZE	49	24	19	6
WEIGHT	[illegible]	22	16	6
FLANGE LOCATION	62	26	31	5
MODULARIZATION	75	31	32	12
STD. LEVEL	[illegible]	21	31	11
DRIVE SYSTEMS:				
SPACE POWER	77	34	30	13
TYPE SYSTEM	[illegible]	29	30	5
TORQUE	[illegible]	32	22	10
R.P.M.	[illegible]	26	22	5
NO OF SHAFTS	[illegible]	22	27	10
THRUST LOADS	40	21	12	7
NO OF BEARINGS AND LOAD	50	19	19	12
FOUNDATION DESIGN	[illegible]	27	25	8
PROCUREMENT SPECS.	[illegible]	31	26	12
ARRANGEMENT DWGS.	[illegible]	19	22	5
INSTRUCTION DWGS.	[illegible]	23	28	7
TECHNICAL/PROCUREMENT MANUAL	74	31	32	11
AUTOMATION AND CONTROL:				
MANUAL/AUTOMATIC	[illegible]	24	0	0
STATION LOCATION	[illegible]	24	26	10
TIME FUNCTION	[illegible]	[illegible]	10	5
SIZE	[illegible]	26	20	10
ELECTRIC WIRING	[illegible]	[illegible]	34	12
PNEUMATIC CONTROLS	[illegible]	[illegible]	[illegible]	12
HYDRAULIC CONTROLS	[illegible]	22	34	12
STATION COMPONENTS	[illegible]	26	16	9
STANDARD SPEC.	[illegible]	2	36	7
A.B.S./C.G.	[illegible]	32	24	10
ARRANGEMENT DWG.	[illegible]	[illegible]	20	5
TECHNICAL/OPERATING MANUAL	[illegible]	38	10	5
MAJOR COMPONENT/SUB-SYSTEMS				
TURBINE COMPRESSOR:				
TYPE	40	21	13	6
NO OF STAGES	[illegible]	17	13	6
RPM	[illegible]	27	12	6
IGV	[illegible]	19	12	5
PRESSURE RATIO	[illegible]	27	18	7
TRIP SPEED	65	33	19	13
MATERIAL/LEAKAGE	[illegible]	33	25	8
GAS TURBINE PROCURE:				
PROCUREMENT SPEC.	[illegible]	32	29	14
ARRANGEMENT DWG.	[illegible]	25	19	7
COMBUSTION CHARACT.:				
TYPE OF FUEL	[illegible]	31	19	9
GAS TEMP.	[illegible]	21	14	2
NO OF NOZZLES	[illegible]	9	16	8
GAS TURBINE PACKAGE:				
FUEL FLOW CONTROL	[illegible]	31	23	7
DRAWINGS	[illegible]	[illegible]	12	6
SPECIFICATIONS	[illegible]	26	26	9
GAS GENERATOR TURBINE:				
NO OF STAGES	[illegible]	14	17	5
GAS FLOW EFFICIENCY	[illegible]	22	17	5
STYLE	[illegible]	23	20	6
TURBINE COLUMN CHARACTERISTICS	[illegible]	22	22	6
GAS TURBINE PACKAGE:				
DRAWINGS	36	14	19	3
SPECIFICATION	65	28	28	9
POWER TURBINE:				
RPM	58	31	17	10
NO OF STAGES	[illegible]	16	22	5
GAS TURBINE PACKAGE:				
DRAWINGS	36	14	19	3
SPECIFICATION	[illegible]	28	29	9
H.P.	[illegible]	33	32	12
AIR FLOW	[illegible]	22	19	5
EXHAUST GAS TEMP	[illegible]	27	21	5

Table 4 - 10
Gas Turbine Propulsion Plant
Evaluation Matrix
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CRITERIA & MULTIPLIER / STANDARDS PARAMETER & TOTALS		A. TECHNICAL FEASIBILITY	B. ECONOMIC POTENTIAL	C. INDUSTRY ACCEPTANCE
		40	40	20
STARTING SYSTEM:				
TYPE	62	29	27	6
CAPACITY	67	31	[illegible]	14
RESERVOIR CAPACITY	56	36	[illegible]	11
PRESSURE	57	30	[illegible]	10
SIZE	69	32	[illegible]	10
STOP STARTS/UNIT TIME	67	37	[illegible]	13
WEIGHT	67	30	[illegible]	10
[illegible]	53	29	[illegible]	7
FLANGE LOCATION	65	22	23	14
ACCESSORY GEAR BOX	59	24	27	8
SPECIFICATION	59	29	[illegible]	[illegible]
INSTRUCTION DWGS	63	29	[illegible]	[illegible]
TECH OPERATING MANUAL	72	34	27	11
LUBE OIL SYSTEM:				
CAPACITY	63	31	21	11
EQUIPMENT RATINGS	62	27	23	12
PRESSURE	49	23	16	10
LUBE OIL CONDITIONS	59	32	16	10
ACCESSORY GEAR BOX	56	24	24	8
SIZE	69	32	27	10
WEIGHT	67	30	27	10
FLANGE LOCATION	65	22	29	14
STANDARD SPEC.	59	29	26	8
STANDARD DWGS.	63	29	26	8
TECH OPERATING MANUAL	72	34	27	11
COOLING SYSTEM:				
CAPACITY	70	35	27	8
COOLING WATER CONDITIONS	60	36	21	13
MATERIALS	72	32	27	13
HEAT TRANSFER CONDITIONS	45	20	17	8
SIZE	66	32	24	10
WEIGHT	64	30	24	10
PACKAGING	57	20	30	7
PROCUREMENT SPECS	70	32	24	14
A.B.S./C.G. APPROVAL	68	24	29	15
ARRANGEMENT DWGS	53	21	24	8
PIPING DWGS.	50	21	22	7
INSTRUCTION DWGS.	55	23	22	10
OPERATING MANUAL	76	30	32	14
FLANGE LOCATION	68	29	25	14
DIST/RESIDUAL FUEL SYSTEM:				
CAPACITY	70	37	22	11
TYPE	54	27	17	10
F.O. TEMPERATURE	57	32	17	8
F.O. PRESSURE	57	32	17	9
FILTER SIZE	56	32	12	14
SIZE	73	34	27	12
WEIGHT	73	32	29	12
H.P.	59	30	24	5
R.P.M.	53	28	20	5
POWER REQ'T.	45	20	20	5
PACKAGING	52	36	16	10
FLANGE LOCATION	56	25	22	9
SETTLER CAPACITY	54	34	13	7
FUEL OIL QUALITY	75	38	20	17
BLENDING/HEATING	66	31	25	10
SLUDGE REMOVAL	51	25	19	7
STANDARD SPECS.	61	29	21	11
PROCUREMENT SPECS	68	32	24	12
A.B.S./C.G. APPROVAL	70	24	31	15
ARRANGEMENT DWGS	55	21	26	8
INSTRUCTION DWGS.	52	19	25	8
TECH. OPERTG. MANL.	74	34	30	10
MAIN PROPULSION GENERATOR:				
H.P.	76	34	30	12
NO OF UNITS	69	29	30	10
R.P.M.	68	31	28	9
ROTATION	67	40	16	11

CRITERIA & MULTIPLIER / STANDARDS CANDIDATES & TOTALS		A. TECHNICAL FEASIBILITY	B. ECONOMIC POTENTIAL	C. INDUSTRY ACCEPTANCE
		40	40	20
RATING	63	36	17	10
TYPE	70	32	30	8
TEMP RATING	61	36	14	11
KVA	70	36	23	11
PHASES	55	27	[illegible]	10
VOLTS	66	34	[illegible]	11
POWER FACTOR	65	37	12	13
HZ.	59	37	17	15
VENTILATION	54	28	[illegible]	[illegible]
SIZE	54	30	23	11
WEIGHT	64	30	23	11
PACKAGING/COMPONENTS	57	24	25	8
VENT STYLE	50	24	[illegible]	7
PRODUCTION SPEC.	53	26	[illegible]	9
A.B.S./C.G. APPROVAL	54	24	[illegible]	11
ARRANGEMENT DWGS.	52	20	24	8
INSTRUCTION DWGS.	53	25	23	10
CALCULATIONS	69	35	22	12
TECH OPERATING MANUAL	65	35	16	14
MAIN PROPULSION MOTOR:				
H.P.	70	31	29	10
R.P.M.	51	25	21	5
ROTATION	70	40	[illegible]	12
RATING	57	34	5	8
TYPE	68	32	23	8
TEMP RATING	61	36	4	11
KVA	67	38	21	8
PHASES	57	27	20	10
VOLTS	68	34	23	11
POWER FACTOR	57	37	11	13
HZ.	69	37	17	15
SIZE	65	30	24	11
WEIGHT	65	30	24	11
A.B.S. CG. APP.	52	19	24	9
PACKAGING/COMPONENTS	57	24	25	8
VENT STYLE	50	24	[illegible]	7
PRODUCTION SPEC.	53	26	[illegible]	9
A.B.S. C.G. APPROVAL	[illegible]	24	[illegible]	11
ARRANGEMENT DWGS.	52	20	[illegible]	8
CALCULATIONS	69	35	22	12
TECH. OPER. MANUAL	65	35	10	14
REDUCTION GEAR:				
RATING	58	31	19	8
TYPE REDUCTION	69	31	27	11
H.P.	59	28	21	10
NO OF UNITS	66	27	30	9
"K" FACTORS	62	32	21	9
EFFICIENCY	55	32	12	11
LOADING	65	34	23	8
[illegible] TORQUE	51	31	15	5
[illegible]	53	33	[illegible]	7
SIZE	62	31	21	10
WEIGHT	61	30	21	10
FLANGE LOCATION	55	27	[illegible]	10
PACKAGING	58	23	25	10
PRODUCTION SPEC.	56	27	22	7
STANDARD DWGS.	48	24	19	5
ARRANGEMENT DWGS.	49	21	20	7
PIPING DWGS.	51	22	23	6
INSTRUCTION DWGS.	59	29	23	7
CALCULATIONS	71	34	25	12
TECH OPERTG MANUAL	73	32	27	14
THRUST BEARINGS:				
TYPE	52	27	11	14
NO OF UNITS	44	17	13	14
PRESSURE RATING	64	32	22	10
LOADING	56	29	17	10
SIZE	55	25	22	8
WEIGHT	55	25	22	8
PACKAGING	51	24	20	7
PRODUCTION SPEC.	49	28	14	7
ARRANGEMENT DWG.	34	25	9	5

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CRITERIA & MULTIPLIER / STANDARDS PARAMETER & TOTALS		A. TECHNICAL FEASIBILITY	B. ECONOMIC POTENTIAL	C. INDUSTRY ACCEPTANCE
		40	40	20
INSTALLATION DWGS	[illegible]	[illegible]	27	11
TECH/PARTS MANUAL	[illegible]	[illegible]	24	17
SHAFTING SYSTEM:				
H.P.	[illegible]	24	19	11
R.P.M.	[illegible]	27	15	8
NO. OF SHAFTS	[illegible]	[illegible]	13	4
MATERIALS/DESIGN	[illegible]	[illegible]	25	14
SIZE	[illegible]	[illegible]	25	8
LENGTH	[illegible]	[illegible]	22	5
WEIGHT	[illegible]	[illegible]	19	5
A.B.S./C.G. APPROVAL	[illegible]	[illegible]	29	15
SPECIFICATIONS	[illegible]	[illegible]	21	11
INSTALLATION DWGS	[illegible]	[illegible]	20	6
CALCULATIONS	[illegible]	[illegible]	15	12
PROPULSION CONTROL SYSTEM:				
TYPE	[illegible]	27	28	12
[illegible]				
R.P.M.				
CYCLE FUNCTION	[illegible]	32	23	12
SIZE	[illegible]	[illegible]	21	8
WEIGHT	[illegible]	[illegible]	19	6
PRESSURE				
FLANGE LOCATION	[illegible]	[illegible]	29	13
STANDARD DWGS.	[illegible]	[illegible]	19	7
PRODUCTION DWGS.	[illegible]	[illegible]	14	6
A.B.S./C.G. APPROVAL	[illegible]	27	25	13
ARRANGEMENT DWGS	[illegible]	[illegible]	19	5
INSTALLATION DWGS	[illegible]	[illegible]	26	6
PIPING DWGS	[illegible]	[illegible]	23	9
OPERATION MANUAL	[illegible]	29	28	10
EQUIPMENT COMPONENTS:				
ACCESSORY GEAR BOX: CAPACITY	[illegible]	32	21	10
TYPE DRIVE	[illegible]	[illegible]	16	7
EFFICIENCY	[illegible]	[illegible]	13	7
NO. OF [illegible]	[illegible]	27	16	7
LOADINGS	52	[illegible]	16	5
SIZE	[illegible]	[illegible]	15	10
WEIGHT	[illegible]	27	15	10
PACKAGING	[illegible]	[illegible]	20	8
STANDARD SPECS	[illegible]	[illegible]	15	8
INSTALLATION DWGS	[illegible]	[illegible]	16	9
TECH/PARTS MANUAL	[illegible]	29	17	12
DEMISTER:				
TYPE	[illegible]	[illegible]	21	4
[illegible]	[illegible]	25	16	9
NO. OF STAGES	[illegible]	[illegible]	15	8
[illegible]	[illegible]	[illegible]	16	13
SIZE	[illegible]	[illegible]	18	10
WEIGHT	[illegible]	[illegible]	17	11
[illegible]	[illegible]	-	21	15
PACKAGING	[illegible]	[illegible]	25	6
STANDARD DWGS	[illegible]	[illegible]	20	5
ARRANGEMENT DWGS	[illegible]	24	22	5
TECH/PARTS MANUAL	[illegible]	[illegible]	29	10
REGENERATOR:				
TYPE	57	[illegible]	13	10
EFFICIENCY	[illegible]	[illegible]	13	13
CAPACITY	[illegible]	24	13	7
GAS FLOW RATE	[illegible]	[illegible]	11	11
AIR FLOW RATE	[illegible]	[illegible]	11	11
TEMPERATURE [illegible]	43	32	10	6
SIZE	65	32	23	10
WEIGHT	67	34	23	10
FLANGE LOCATION	74	35	26	13
STANDARD SPECS.	52	22	16	8
INSTALLATION DWGS	[illegible]	27	23	8
TECH/PARTS MANUAL	[illegible]	32	24	10
PACKAGING	46	23	17	6
EXHAUST GAS BOILER:				
CAPACITY	57	16	33	8
TYPE	73	22	24	7
HEAT TRANSFER	64	35	21	8

CRITERIA & MULTIPLIER / STANDARDS CANDIDATES & TOTALS		A. TECHNICAL FEASIBILITY	B. ECONOMIC POTENTIAL	C. INDUSTRY ACCEPTANCE
		40	40	20
FEED CONDITIONS	56	25	21	10
STEAM RATE	70	35	26	[illegible]
EXHAUST [illegible]	48	25	17	6
SIZE	70	35	28	7
WEIGHT	67	35	25	7
ENG. AR. ARR.	56	25	23	7
PACKAGING	51	25	19	7
SPECIFICATIONS	71	31	30	10
DRAWINGS	47	23	17	7
A.B.S./C.G. APPROVAL	67	24	31	12
TECH/PARTS MANUAL	65	27	27	11
FLANGE LOCATION	72	28	34	10
SOUND ATTENUATION CHAMBERS:				
EFFICIENCY	48	30	13	5
D.B. CONTROL	67	33	26	8
TYPE	63	29	27	7
FRICTION LOSSES	56	31	18	7
VIBRATION	34	12	14	8
CAPACITY	52	27	6	9
SIZE	52	27	18	7
FLANGE LOCATION	63	27	27	9
WEIGHT	62	27	28	7
ENG. AR. ARR.	46	25	14	7
PACKAGING	46	25	15	6
STANDARD SPECS.	66	34	23	9
ARRANGEMENT DWGS	50	25	17	8
TECHNICAL MANUALS	74	29	27	12
STARTING DEVICES:				
TYPE - HYD/PNEU	63	34	22	7
EFFICIENCY	45	19	21	5
TORQUE	54	30	18	6
COUPLING DEVICES	48	28	13	7
RECOVERY RATE	35	16	11	8
COOLER TYPE	39	19	13	7
DUTY CYCLE	66	37	20	9
SIZE	55	32	15	8
R.P.M.	50	25	18	7
WEIGHT	52	27	17	8
TYPE OIL	62	37	14	11
ACCESSORY GEAR BOX	54	29	18	7
ARRANGEMENT DWGS	53	30	17	6
OPERATING MANUAL	63	27	24	12
SPECIFICATIONS	70	31	30	9
FUEL OIL PURIFIER/HEATERS:				
TYPE FUEL	49	28	12	9
OIL QUALITY	67	31	23	13
EFFICIENCY	42	20	14	8
RATING	50	27	14	9
CAPACITY	59	34	14	11
HEAT TRANSFER	53	29	18	6
SIZE	59	30	22	7
WEIGHT	65	30	28	7
FLANGE LOCATION	63	27	27	9
PACKAGING	64	30	25	9
SPECIFICATIONS	62	30	23	9
DRAWINGS	45	22	17	6
OPERATING MANUAL	73	32	30	11
FUEL OIL SERVICE PUMP:				
CAPACITY	72	36	24	12
TYPE	73	37	25	11
[illegible]	72	37	21	14
EFFICIENCY	53	25	21	7
H.P.	55	28	21	6
R.P.M.	49	22	18	9
TYPE	54	28	16	10
SIZE	61	31	21	9
WEIGHT	60	31	21	8
PACKAGING	72	35	24	13
FLANGE LOCATION	67	27	32	8
SPECIFICATIONS	62	28	25	9
DRAWINGS	48	23	19	6
OPERATING MANUAL	65	32	21	12

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STANDARDS PARAMETER & TOTALS / CRITERIA & MULTIPLIER		A. TECHNICAL FEASIBILITY	B. ECONOMIC POTENTIAL	C. INDUSTRY ACCEPTANCE
		40	40	20
FUEL OIL FILTRATION UNITS:				
CAPACITY	50	25	1[illegible]	11
TYPE	62	32	23	7
RATING	53	27	14	12
PRESSURE DIFFERENTIAL	48	26	[illegible]	11
FILTER SIZE	44	36	16	12
OIL QUALITY	74	37	20	17
MATERIALS	51	25	20	6
SIZE	52	31	11	10
WEIGHT	51	28	11	12
PACKAGING	53	24	17	12
SPECIFICATIONS	48	25	13	9
DRAWINGS	42	2[illegible]	15	6
TECH/SPARE PARTS MANUAL	58	27	21	10
FLANGE LOCATION	59	20	27	12
FUEL OIL ANALYSIS UNIT:				
TYPE	60	23	28	9
EFFICIENCY	23	10	10	3
RATING	49	27	17	5
POWER REQUIREMENTS	44	27	20	7
SIZE	54	34	13	7
WEIGHT	52	32	13	7
PACKAGING	46	20	17	9
SPECIFICATIONS	48	26	13	9
DRAWINGS	42	21	15	6
OPERATING MANUAL	48	26	21	11
FLANGE LOCATION	61	23	26	12
LUBE OIL COOLER:				
TYPE	60	34	21	5
EFFICIENCY	29	16	8	5
CAPACITY	63	34	24	5
NUMBER	67	31	24	12
SIZE	60	30	25	5
WEIGHT	60	30	25	5
WATER SIDE CONDITIONS	50	30	11	9
C.W. CONDITIONS	50	30	11	9
PACKAGING	60	28	22	10
SPECIFICATIONS	45	23	13	9
DRAWINGS	38	17	15	6
OPERATION'S MANUAL	62	24	25	11
FLANGE LOCATION	68	33	25	10
LUBE OIL SERVICE PUMPS:				
CAPACITY	64	34	23	7
EFFICIENCY	47	25	15	7
R.P.M.	55	31	17	7
H.P.	67	38	2[illegible]	8
RATINGS	39	22	12	5
TYPE	60	35	13	12
PACKAGING	61	27	25	9
SIZE	54	25	21	8
WEIGHT	46	25	13	8
SPECIFICATIONS	50	21	21	8
DRAWINGS	45	22	17	6
OPERATING MANUAL	55	25	19	10
FLANGE LOCATION	70	33	27	10
LUBE OIL PURIFIERS/ HEATERS:				
TYPE	42	25	9	9
OIL QUALITY	66	34	17	15
CAPACITY	58	30	16	12
MESH	43	22	11	10
HEAT TRANSFER	40	17	15	8
PRESSURE DROP	41	15	14	12
EFFICIENCY	23	12	7	4
PACKAGING	53	23	17	13
SIZE	57	31	15	11
WEIGHT	55	29	15	11
FLANGE LOCATION	63	24	26	13
SPECIFICATIONS	47	[illegible]	13	9
DRAWINGS	41	20	15	[illegible]
OPERATING MANUAL	57	27	20	12
COOLING SYSTEM HEAT EXCHANGER	34	10	16	8
NUMBER	59	2[illegible]	24	10

STANDARDS CANDIDATES & TOTALS / CRITERIA & MULTIPLIER		A. TECHNICAL FEASIBILITY	B. ECONOMIC POTENTIAL	C. INDUSTRY ACCEPTANCE
		40	40	20
EFFICIENCY	41	18	17	6
TYPE	60	33	24	3
CAPACITY	64	34	25	5
RATING	55	33	20	2
SIZE	55	27	21	7
WEIGHT	5[illegible]	24	21	[illegible]
FLANGE LOCATION	63	33	25	[illegible]
PACKAGING	61	27	25	[illegible]
SPECIFICATIONS	50	29	12	[illegible]
DRAWINGS	40	17	15	8
OPERATING MANUAL	63	24	23	16
APPROVALS	39	11	22	6
TURBINE COOLING AIR FANS:				
TYPE	39	20	14	6
CAPACITY	52	25	21	6
RATING	50	33	10	7
EFFICIENCY	45	25	10	10
H.P.	49	24	16	9
R.P.M.	34	19	10	5
PACKAGING	48	20	20	8
FLANGE LOCATION	60	30	20	10
SPECIFICATIONS	47	21	18	8
DRAWINGS	44	23	15	6
OPERATING MANUALS	57	31	15	11
SHAFT BRAKE:				
HEAT DISSIPATION	45	23	11	11
H.P. RATING	57	30	15	12
COOLING MEDIUM	57	35	10	12
TYPE	54	27	19	8
TIME CYCLE	67	38	20	9
SIZE	47	29	13	5
WEIGHT	48	30	13	5
SPECIFICATIONS	50	25	17	8
FLANGE LOCATION	58	25	23	10
DRAWINGS	46	23	15	8
OPERATING MANUALS	62	29	23	10
CLEARENCES	60	36	11	13
CONTROLS/ INSTRUMENTATION:				
NO. OF CONTROL FUNCTIONS	37	.24	8	5
NO. OF MONITORING FUNCTIONS	33	20	8	5
RESPONSE TIME	32	16	8	8
RELIABILITY	48	32	8	8
NO. OF INTERLOCKS	56	32	16	8
TYPE-PNE/HYD/ ELECTRIC	41	20	16	5
POWER REQUIREMENTS	41	24	12	5
SIZE	33	16	10	2
DEGREE OF CONTROL	32	16	10	6
CLASSIFICATION	20	10	8	2
PACKAGING	44	30	8	6
SPECIFICATIONS	29	20	4	4
DRAWINGS	16	8	4	4
MANUALS	32	24	4	4
ACCESSORIES/[illegible]:				
ALARM PANELS	22	10	8	4
DISPLAY PANELS	22	10	8	4
NO. OF PANELS/STATION	25	10	10	5
TYPE RECORDERS	31	16	10	5
POWER REQUIREMENTS	32	16	10	6
ENV. ENVELOPE	32	20	8	4
SIZE	20	8	8	4
PACKAGE	22	8	8	6
SPECIFICATIONS	22	10	8	4
DRAWINGS	22	10	8	4
MANUALS	32	20	8	4
REPAIRS/MAINTENANCE/ PARTS				
QUALITY CONTROL	67	27	30	10
DURABILITY	33	18	10	5
CORROSION	47	23	18	6
NATIONAL STANDARDS	53	20	26	7

Table 4 - 10
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matrix attached to this report. (See Tables 4-2 and 4-10) The grades were then reviewed by *two* levels of engineering management. The total grade for each standards candidate was used for the final technical selection; those candidates which received a score of 70 was chosen so that a grade of more than 25% for technical feasibility or economic potential would be required before a candidate could be selected for further study. It was also concluded that in order to choose successful candidates, a score well above the *50%* average was required.

4.5 DETERMINATION OF STANDARDS

4.5.1 EVALUATION OF LEVEL AND TYPE

The $otential of each of the standards parameters was investigated by "type" for performance, operating characteristics, interface, packaging and software type and at the "levels" of total package, major system, main equipment/sub-system, and equipment/component

The potential of each standards parameter was evaluated for use in "standards" at its respective "type" and "level. " A review of the parameters with the greatest potential indicated that the same type parameters appeared at more than one level and many parameters of different types were interdependent. Since many similarities existed between parameters at different levels and types, it was decided to group the parameters into logical categories, thereby synthesizing the "standard.1"

4.5.2 GROUPINGS OF PARAMETERS

The total package level, Group 1, consists of standards parameters which can be utilized to design the total propulsion plant. Table 4-3 is the Group 1 listing for the steam propul-. sion plant.

The Systems/Equipment Modules form Group II. The primary standards parameters for each module would be its interface and packaging; the supporting standards would be the performance and operation of the module as a system as well as its component equipment where applicable. The modules are at two levels, viz. Major Equipment/SubSystem and Equipment/Component. Table 4-4 is the Group II listing for the steam propulsion plant.

Similar logic was-used to develop Group III, Equipment Envelopes and Group IV, Individual Equipment/Components. Tables 4-5 and 4-6 are the Group III and Iv listings for the steam propulsion plant.

A detailed discussion of the grouping of the four major categories can be found in subsection *4.5.3.*

4.5.2.1 Evaluation of Steam Turbine Propulsion Standards Parameters

After completion of the grading sheets, the first step used in this evaluation was to select the parameters which received a score above 70 total points. To further simplify the evaluation, the parameters were inspected for their interrelationship with others: e. g., the steam propulsion plant's SHP, fuel rate, steam conditions, condensate conditions, feed conditions, number of heating stages, and number of boilers are interdependent with each other and the standard heat balance, general specifications and procurements specifications.

> NOTE: It is interesting to note that although the standard engine room arrangement received a grade which was insufficient to consider it for further evaluation and possible standardization, arrangement drawings, piping drawings, preformed pipe and piping interfaces, which are interdependent with engine room arrangement, received grades of sufficient magnitude for standardization selection. This appeared inconsistent since it was thought that the subordinate parameters should have received lower scores than the engine room arrangement . However, it can be expected due to the requirement for a standard arrangement in order to standardize the drawings *or* the preformed pipe. Further inspection of the separate criteria grades, rather than the total grade, supported the hypothesis that the subordinate parameters are rated lower technically, but received higher total grades since each had a higher potential for cost savings than the engine room arrangement. The question then arises: does the engine room arrangement warrant a higher economic potential since it will allow the acceptance, for further study, of the subordinate parameters whose potential is directly related to and part of that of the engine room arrangement's economic potential? It was concluded that the engine room arrangement and its subordinate parameters should be economically analyzed. Should this analysis result in promising cost savings, the subordinate parameters should be selected for further study to ascertain their relative economic potential.

One important factor which is discussed in greater depth in paragraph 4.6.3 is that such interrelated parameters are only feasible on vessels of the same type, class, and power range. This fact could have eliminated these parameters from consideration. However, results of the forecast indicate a large number of ships of similar size and SHP predicted for construction through 1985. Table 4-11 is a listing of ships by type and size with the quantity of ships forecast and the number of equivalent propulsion plants required for each. It is apparent from this chart that twenty standard plants would cover the entire requirements for standard plants for the period to 1985.

Evaluation of the grades of the listed parameters dictate that the following be considered standards parameters at the total package level for the steam turbine propulsion plant:

SHP	Standard Specifications
Fuel Rate	Procurement Specifications
Steam Conditions	Engine Room Arrangements
Condensate Conditions	Standard Drawings
Heating Stages	Arrangement Drawings
Number of Boilers	Piping Drawings
Structural Modules	Installation Drawings
Heat Balance	Calculations
Coast Guard and ABS Approvals	

The SHP, fuel rate, steam conditions, condensate conditions, number of heating stages, number of boilers and the heat balance are interrelated. An inspection of selected parameters at the major systems, major equipment/sub-systems,

	Possible Standard Plants		No. of Ships	No. of Stds.
1.	Cont Car./ROR	14 - 20K DWT	38	3
2.	Barge car.	22 - 28K "	33	3
3.	Bulk Car.	19 - 20K "	10	1
4.	Bulk Car./LPG/Oil Tanker	25 - 45K "	93	4
5.	Bulk Car./OBO/LNG/Oil Tkr	64 - 100K "	122	4
6.	Oil Tankers	120 - 150K "	19	2
7.	Oil Tankers	225 - 265K "	20	2
8.	Oil Tankers	400	15	1
			350	20

Table 4 - 11 NUMBER OF REQUIRED STANDARD PLANTS

equipment/components levels indicates that the same type of parameters are found. The following are some examples of similar parameters at these levels:

Steam Systems:
  Steam Conditions

Boilers:
  Capacity
  Fuel Rate
  Superheater Steam Conditions
  Feed Conditions

Main Turbines:
  HP
  Steam Conditions

Condensate Pump:
  GPM
  Rated Head
  RPM
  Type

First Stage Heater
  Capacity
  Steam Conditions
  Condensate Conditions

All of the above define the system's or equipment's performance, operating characteristics, type, quantity, etc. These types of standards parameters found at every level are necessary to define the total package - the steam turbine propulsion plant. Therefore, in order to standardize the total propulsion plant, each system/equipment must be identified and defined. Once this is accomplished, heat balance diagrams, general and procurement specifications also become standardized.

As previously stated, should the engine room arrangement be made standard, the arrangement drawings, piping drawings, preformed pipe-and piping interfaces can also be made standard. Inspecti,ng the parameters at the lower levels for this type of standard, one finds the following possible standards:

Steam Systems:
- Preformed Pipe
- Piping interfaces

Condensate System:
- Piping Interfaces

These standards can only be developed if the engine room arrangement becomes standard and-the entire propulsion plant's system/equipment are identified and defined. Therefore, it appears feasible *to* group the standards parameters for the total package level together since they are interrelated. This grouping will be called GROUP 1 - Total Propulsion Plants. Also contained in this group are U.S.C.G. and A.B.S. approvals, installation drawings and calculations which result from the standardization of the other candidates.

Line shafting shipping supports (at the major systems level) and structural modules (at the total package level) are parameters which also received grades sufficient to be chosen for future study. The supports in shipping of the line shafting are, of necessity, already standard and/or determined by the manufacturers and/or shipping agents. Therefore, no further consideration will be given to this candidate.

The standard structural module is a parameter which is similar to a shipyard standard module concep~ currently used by many shipyards. One such shipyard estimated that the difference between building a particular structural module separate from the ship rather than building on the ship resulted in cost savings of approximately $50,000. A more definite Break-. down of this cost savings was not given by that shipyard.

Evidence supporting modules as viable standards are also found at the lower levels:

Turbines with
- Condenser
- Air Ejector
- Controls
- Piping, fittings, etc.

Condensate Pumps skid mounted with:
- Piping, fittings, etc.
- Prime Mover
- Controls

1st Stage Heater mounted with:
- Gland Leak-off Condenser
- Atmospheric Drain Tank
- 2nd State Heater (if exists - L.P.)

Main Feed Pump mounted with:
- Piping, fittings, etc.
- In-Port Feed Pump
- Controls
- Prime-Movers

L.O. Purifying System Module:
- L.O. Purifier
- L.O. Purifier Pumps
- L.O. Sludge Tank
- L.O. Heater
- Piping, fittings, etc.

F.O. Service System Module:
- F.O. Service Pumps
- F.O. Heaters
- F.O. Strainers
- Prime-Movers
- Controls
- Piping, fittings, etc.

H.P. Heaters Module:
3rd Stage Heater
4th Stage Heater
Piping, fittings, etc.

Ranking these in the order of the average total grades received results in a listing as follows (with total numerical grade):

1. Condensate Pump Module - 90
2. Main Feed Pump Module - 86
3. F.O. Service System Module - 82.5
4. H.P. Heaters Module - 80
5. Turbine with Condensor and Air Ejector - 77
6. Structural Modules - 77
7. L.O. Purifying System Module - 72.5
8. 1st Stage Heater Module - 71

These module type standards are described in paragraph 4.5.3. They are grouped together for further evaluation in Group II - System/Equipment Modules.

The next group of successful parameters (Group III) to be identified was the location of piping, wiring and foundation interface points. These candidates are found at the Major Equipment/Sub-System Level and at the Equipment/Component Level. As will be discussed in greater detail in paragraph 4.5.3, the piping interface locations are defined by an imaginary envelope encasing the equipment or system. This is done with the purpose of allowing competitive designs while maintaining dimensional standards between manufacturers. If a manufacturer had to change, his design to meet a standard interface location, he would find it an unacceptable standard. (The module concept also contains this envelope which defines interface locations)

According to the grades received, the equipment which are" viable candidates for the envelope type standard are listed in relative order of feasibility as follows:

1. Boiler
2. Main Turbine (control location only)
3. Air Preheater
4. Economizer
5. Condensate Pump
6. F.O. Service System (covered under GROUP II)
7. Main Circulating Pump
8. L.O. Purifier
9. Bridge Remote Controls
10. F.O. Service Pumps
11. L.O. Service Pumps
12. Air Ejector

Since these parameters are related in that they fall under the same concept (enveloped), they are arranged together into GROUP Ill - Equipment Envelopes.

The remaining successful parameters related to individual equipment or components. These are classed as GROUP IV - Individual Equipment/Components. Contained in this group are such standards parameters as "shipped assembled, protection and packing, controls, procurement or general specifications, approved installation drawings, mounting interfaces, calculations and technical manuals." These items are flexible and general enough to allow industry acceptance. Candidates such as materials, reliability, durability, heat transfer coefficient and other design specifications received low grades due to poor industry acceptance. For the most part, this was the reason why most of the less desirable candidates received low grades. The second most prevalent reason was due to technical infeasibility. In addition, candidates which showed little or no economic potential received low grades.

Parameters within GROUP 1, Total Propulsion Plants, and GROUP IV, Standard Equipment, may be interchangeable. Standards parameters, such as capacity, pressures, liquid (or vapor) conditions and other performance and operating characteristics found in GROUP I can also be listed under GROUP IV. This case could arise whether GROUP I standards were or were not used. If a standard total powerplant did not meet special requirements necessitated by the type of vessel, individual standard equipment, GROUP IV Standards, can be utilized including the required performance and operating characteristics. When Standard Propulsion Plants, GROUP 1, become universally accepted, the standard equipment items, GROUP IV, will no longer be required except as a part of Group 1.

The following tabulation, Table 4-12, lists . the selected candidates for systems/equipment and the groups they coincide with. Tables 4-3 through 4-6 tabulate the groups with the appropriate candidates and pertinent equipment or systems with their relative rank of potential.

SELECTED PARAMETERS	GRADE	GROUP
<u>Total Package Level</u>:		
Steam Propulsion Plant:		
SHP	93	I
Fuel Rate	77	
Steam Conditions	96	
	90	
Heating Stages	87	
No. of Boilers	86	
Structural Modules	77	II
Heat Balance	96	I
St'd. Specs.	86	
Procurement Specs.	80	
Coast Guard Appv'ls	77	
Standard Dwgs.	79	
Installation Dwgs.	70	
Arrangement Dwgs.	76	
Piping Dwgs.	71	
Calculations	83	
<u>Major Systems</u>:		
Steam Systems:		
Steam Conditions	97	
Pipe Sizing	86	
Preformed Pipe	73	
Piping Interfaces	75	
Calcs. & Ht. Bal.	85	
Condensate System:		
Condensate Conditions	77	
Piping Interfaces	71	
Heat Balance	85	
Feed System:		
Feed Conditions	85	
Steam Conditions	84	
Heat Balance	83	
Line Shafting System:		
HP	91	
(Support in Shipping)	72	

Table 4 - 12
List of Selected
Candidates

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SELECTED PARAMETERS	GRADE	GROUP
Major Equipment/Sub-System Level:		
Boilers:		
Capacity	86	I
Generating Surface	77	
Fuel Rate	78	
S.H. Steam Conditions	91	
Reheat/Non-Reheat	84	
Inlet Water Temp.	80	
Inlet Water Press	72	
Limiting Size & Wt.	82	III
Location of S.H. Out	74	
Location of S.H. In	74	
Location of Feed In	74	
Location of Fuel Lines	77	
Piping to Interface Loc.	84	
Shipped Assembled	78	IV
Appv'd Inst. Dwgs.	79	
Technical Manuals	82	
Main Turbines:		
HP	83	I
Steam Conditions	82	
Limiting Size & Wt.	72	II or III
Module w/Cond & Air Ejector	75	II
Loc. of Turbine Cont.	77	III
Procurement Specs.	78	IV
Condenser:		
Capacity	83	I
Temp. Stem	73	
Temp. Condensate	72	
Temp. Circ. Water	71	
Circ. Water GPM	80	
Limiting Size & Wt.	73	II or III
Module	85	II
Specifications	82	IV
Appv'd Inst. Dwgs.	71	

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SELECTED PARAMETERS	GRADE	GROUP
Major Equipment/Sub Sys. Level:		
Condensate Pumps:		
GPM	90	I
Rated Head	85	
RPM	78	
Prime Mover	90	
Power Required	80	
Type	77	
Limiting Size & Wt.	75	II or III
Suct & Disch. Size & Loc.	74	III
Foundation & Bolting	72	II
Controls	71	IV
Module	90	II
Shipped Assembled	85	IV
Piping to Interfaces	76	III
Specifications	83	IV
Technical Manuals	77	
Appv'd Dwgs.	77	
1st Stage Heater:		
Capacity	81	I
Stm. Conditions	70	
Condensate Conditions	71	
Module	71	II
Limiting Size & Wt.	70	II or III
Shipped Assembled	71	IV
Specifications	78	
Atmospheric Drn. Tank, Gland Leak-off Cond., & 2nd Stage tr. same as 1st Stage Heater		
Air Ejector:		
Size & Loc. of Piping	71	III
Attached to Cond.	71	II
Shipped Assembled	70	IV
D.C. Heater (DFT)		
Capacity	74	I
Steam Inlet Cond.	70	
Condensate & Feed Conditions	71	

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SELECTED PARAMETERS	GRADE	GROUP
Major Equipment/Sub System Level:		
Main Feed Pump:		
Capacity	80	I
Head	80	
Prime Mover	73	
Suction & Discharge Cond.	81	
Pump Type	79	
Module	86	II
Controls	78	IV
Shipped Assembled	85	
Specifications	80	
Approved Dwgs.	71	
Technical Manual	80	
3rd Stage Heater:		
Capacity	77	I
Steam Conditions	71	
Module w/4th Stge	80	II
4th Stage Heater Same as 3rd Stage Htr		
L.O. Service System:		
Capacity		I
L.O. Purifying System:		
Capacity	72	I
Skid Mounted	76	II
F.O. Service System:		
Capacity	83	I
F.O. Conditions	74	
Location of Piping	73	II or III
Skid Mounted	89	II
Auxilary Turbines:		
Steam Conditions	76	I
Coupling Method	72	
Controls	71	
Technical Manuals	72	
Control System:		
Type	74	I
Environmental Cond.	73	IV

Table 4 - 12

Sht 4 of 7

SELECTED PARAMETERS	GRADE	GROUP
Major Equipment/Sub-System Level:		
Reduction Gears:		
HP	77	I
Articulated or Locked Train dependent on size	72	
Integral Thrust Bearing	75	
Limiting Size & Wt.	71	III
Matched Gears	70	IV
Shipped Matched or Assembled	74	
Packing & Protection	71	
Calculations	72	
Thrust Bearing:		
Type	70	I
Shipped Assembled	70	IV
Housed w/Gears	80	I
Journal Bearing:		
Lubricating Method	80	I
Main Circulating Pump:		
Capacity	76	I
Head	76	
Power	74	
Prime Mover	80	
Type	73	
Suct. & Disch. Size & Loc.	73	III
Economizer:		
Feed Conditions	87	I
Attached or Not	75	IV
Loc. & Size of Feed	75	III
Loc. & Size of F/ue Gas	73	
Shipped ready for assembly	73	IV
Air Pre-Heater:		
Capacity	80	I
Air Conditions	75	
Limiting Size & Wt.	71	III
Size & Loc. of Air	77	
Size & Loc. Steam or F/ue	75	
On Boiler	76	IV
Sepcifications	70	

Table 4 - 12

Sht 5 of 7

SELECTED PARAMETERS	GRADE	GROUP
Equipment/Component Level:		
Forced Draft Blower:		
CFM	84	I
Pressure	74	
Type	77	
Specs.	71	IV
Boiler Controls:		
R&M	70	IV
L.O. Coolers:		
Mounted on Red. Gear or Sump	73	II
L.O. Service Pumps:		
Capacity	73	I
Pressure	78	
H.P. Required	70	
Prime Mover	79	
Type	75	
Limiting Size & Wt.	70	III
Suct. & Disch. Size & Loc.	71	
Mounting Interfaces	74	IV
Mounted on L.O. Sump	71	II
Technical Manual	75	IV
L.O. Strainers:		
Capacity	73	I
Mounted on Cooler or Red. Gears	77	II
L.O. Heaters:		
L.O. Purifying Module	72	II
L.O. Purifier:		
Capacity	75	I
Type	77	
Prime Mover	70	
Limiting Size & Wt.	70	II or III
Loc. & Size of L.O.	70	
Loc. & Size of Sludge Tank	75	
L.O. Purifying Module	81	II

Table 4 - 12

Sht 6 of 7

SELECTED PARAMETERS	GRADE	GROUP
Equipment/Components Level:		
F.O. Service Pumps:		
Capacity	79	I
Pressure	79	
Type	84	
Prime Mover	84	
Power Required	73	
Limiting Size & Wt.	75	III
Suct. & Disch. Size & Loc.	72	
F.O. Service Module	84	II
Approved Inst. Dwgs.	73	IV
F.O. Heater:		
Limiting Size & Wt.	70	III
Type	78	I
F.O. Service Module	84	II
F.O. Strainer:		
Type	70	I
F.O. Service Module	73	II
Engine Room Controls:		
Method of Control	74	I
Environmental Requirements	73	IV
Bridge Controls		
Interface Locations	72	III

Table 4 - 12

Sht 7 of 7

4.5.2.2 Evaluation of Diesel Propulsion Plant Standards Candidates

The results of the grades assigned the diesel propulsion plant standards parameters were not conclusive. This is illustrated in Figure 4 - 13, where it can be seen that the grades are inconsistent. The grading was such that two of the three evaluators assigned grades above 70 whereas the third evaluator assigned grades so low that the average grade fell below that required for further consideration. In any statistical analysis, figures which are obviously in error are rejected. This warrants the rejection of that one point. However, in this application the inconsistencies appeared throughout the grading.

It, therefore, became apparent that-the numerical evaluation, such as the one used for steam turbine plant, was not going to result in a meaningful selection of standards parameters for the medium speed diesel plant. For this reason, and supported by the findings of the forecast report (which showed the number of diesel powered ships to be contracted for until 1985 is minimal), it was considered reasonable not to reevaluate the medium speed diesel plant standards parameters. However, it is believed that there are some candidate components in a diesel propulsion plant which should be considered for standardization. In order to establish what these candidates are, industry recommends-tions were taken into account and also, diesel plant equipment and systems whfch are similar to those in the steam turbine plant were considered. As a result, and in addition to the "Group I "total diesel propulsion plant standarff ', several module type Group II standards were found to be feasible standards candidates. *Most* of these modules, such as the fuel oil service system, lube oil system, etc., are already evaluated in the steam plant technical analysis. They will not be re-evaluated here. However, some equipment and/or systems which are unique to the diesel propulsion plant can be evaluated. The most likely diesel plant candidates for Group II standards are found to be the "Diesel Accessary Rack Module" and the "Diesel Starting Air System Modeule".

Some of the individual components such as starting air compressors may also prove to be good candidates for standardization in the Group IV category of standards..

CRITERIA & MULTIPLIER / STANDARDS PARAMETERS & TOTALS		A. TECHNICAL FEASIBILITY				B. ECONOMIC POTENTIAL				C. INDUSTRY ACCEPTANCE			
		40				40				20			
EVALUATOR		1	2	3	AVG.	1	2	3	AVG.	1	2	3	AVG.
<u>TOTAL PACKAGE</u>													
DIESEL PROPULSION:													
SHP & OVERLOAD CAP.	83	40	35	36	37	40	35	24	33	16	15	8	13
ENG. RM. ARR'G'T.	65	20	35	30	28	12	40	30	27	6	20	5	10
HEAT TRANS. CALCS.	65	36	35	28	33	28	20	24	24	4	15	5	8
INST. DWGS.	60	24	35	16	25	30	30	24	28	8	7	6	7
PIPING DWGS.	64	30	25	20	25	32	35	20	29	10	15	6	10
ABS & C.G. APPV'L	69	36	25	16	26	36	40	16	30	18	15	5	13
<u>MAJOR SYSTEMS</u>													
DRIVE SYS: HP	76	40	35	36	37	32	25	24	27	20	7	8	12
ABS & C.G. APPVL.	63	36	10	16	21	36	40	10	29	18	15	5	13
INST. DWGS.	48	28	0	24	17	32	40	10	27	8	0	5	4
<u>MAJOR EQUIP./ SUB-SYSTEMS</u>													
EXHAUST SYS: PIPING & DUCT. TO INTERFACE	60	32	25	16	24	32	35	16	28	12	7	5	8

TABLE 4 - 13 SAMPLE OF DIESEL EVALUATION GRADES

The above selected module standards are in use as company standards -in other indust~ies (offshore oil drilling and stationary power plant) and it was recommended that they be applied to the marine industry. A description of the total package standard is given in paragraph 4.5.3.1. Examples of modules are given in paragraph 4.5.3.2.

4.5.2.3 Evaluation of Gas Turbine Propulsion Plants

1. General

The evaluation of Gas Turbine Propulsion follows the same procedures used in evaluation of the Steam Propulsion Plant. A system waterfall chart, Figure 4 - 3 was prepared. This chart was used to systematically analyze the Gas Turbine Plant for the identification of standards . parameters by type and level. This analysis resulted in the" standards parameters matrix, Table 4 - *9*, utilizing the criteria of technical feasibility, economic potential and industry acceptance and numerically grading each parameter by type at each applicable level,

The grading system and selection analysis is the same as that used for steam in that parameters which were graded at 70 points and above (of *a* possible 100) were selected for further economic analysis. The selection process revealed that parameters for standardization were as follows:

At the total package level -

S.H.P.

Vibration Analysis

Number of Units

Structural Modules

Ducting Efficiency

Calculations

Technical/Operations Manual

At the major system level -

<u>Gas Turbine Package</u>

Intake Temperature

Humidity

Assembly of Package

Installation Drawings

Technical Manual

<u>Intake and Exhaust System</u>

Flange Locations

Size and Weight

<u>Auxiliary Support Systems</u>

Modularization

<u>Drive Systems</u>

Horsepower

At the Major Equipment/Sub-System level -

<u>Power Turbine</u>

Horsepower

Cooling System

Capacity

Cooling Water Conditions

Materials

Specifications

Technical/Operating Manual

Distillate/Residual Fuel System

Capacity

Size and Weight

Fuel Oil Quality

Agency Approval

Technical/Operating Manual

Main Propulsion Generator

Horsepower

Rotation

At the Equipment/Component level -

Exhaust Gas Boiler

Type

Steam Rate

Size

Weight

Specifications

Flange Location

Fuel Oil Filtration Unit

Oil Quality

2. Analysis

A. It appears from the foregoing that while there are parameters that may result in adopting some components for standardization, packaging of components within the total Gas Turbine Envelope is already an accomplished fact. Thus, the breakdown of the gas turbine itself into components for consideration appears not to be justified. There is a degree of interrelation between the total package and the three lower levels. For example:

Inlet and Exhaust System

Flange Location

Modularization

Size - Number of Units

Weight - Vibration Analysis

Exhaust Gas Boiler

Ducting Efficiency

Silencers, plenum chambers regenerators and demisters while not qualifying for further consideration are obviously components of this system and would be included in the modular concept. Another example:

Gas Turbine Package

Compressor -

Combustion Chambers -

Gas GeneratorTurbine

Power Turbine

Accessory Gas Box

Control

Again, the foregoing parameters did not qualify for further consideration but are selected in module form.

B. At the Major Systems level, the parameter which qualified was Modularization and at the next lower level, Major Equipment/Sub-Systems the following qualified:

Cooling System

Distilled/Residual Fuel System

Fuel Oil Service Pump

Fuel Oil Filtration Unit

The following systems could be considered for selection as standards candidates on the basis that they are similar to the ones in the steam plant systems which were selected for standardization:

Fuel Oil Systems

Lube Oil Systems

Cooling Water Systems

These systems already received consideration during evaluation of the Steam Turbine Propulsion System.

4.5.3 DESCRIPTION OF STANDARDS

Groups I through IV Standards as developed in 4.5.2 are listed below:

Group I	Total Propulsion Plant Standards
Group II	System/Equipment Modules Standards
Group III	Equipment Envelopes Standards
Group IV	Individual Equipment/Components Standards

During the next sub-task of this study, several candidates in each group will be tested by economic analysis to determine the cost savings which can be realized by utilization of these standards. initial reaction of manufacturers to the proposed standards has been generally favorable and considerable interest has been expressed.

4.5.3.1 GROUP I Total Propulsion Plant Standards.

This group of standards are documents which contains the technical information in standard format which is necessary to define and describe machinery which collectively form a standard propulsion plant and cover finite horsepower ranges. Within each standard horsepower range are definitions of the major components as to their performance, type, description, operating characteristics, size (max.) and weight (max.).

The following standard ranges are listed by power plant type.

Steam Turbine Plants	15 - 17,500 SHP
	24 - 26,000 SHP
	28,5oo - 32,000 SHP
	36 - 40,000 SHP
	43 - 45,000 SHP
	50,000 SHP

Diesel Engine Plants -	8- 1o,ooostw
	12 - 14,000 SHP (2-Eng/Shaft)
Gas Turbine Plants	8- 12,500 HP Heavy Duty
	15 - 30,000 HP tieavy Duty
	20 - 25,000 HP Aircraft Type
	30,500 HP Aircraft Type .
	35 - 40,000 HP Aircraft Type
	45 - 60,000 HP Heavy Duty

The above power plant ranges agree with the requirements of ships forecast through 1985. A format which can be used for this type of standard follows. It illustrates the type of information required in the standard. Based on equipment which is available in the industry now, and also based on estimated performance and -operating characteristics as established in 4.5.2.1, the parameters for Standardization at the total plant level are listed in the pages following for a 24,000 to 26,000 SHP Standard Steam Propulsion Plant and a 12,000 to 14,000 SHP Standard Diesel Propulsion Plant.* Other preliminary descriptions of total plants, subject to refinement as the Standards are developed, may be found in Appendix 6.1.

* These two total plant standards will be economically analyzed in Subtask.3.

4.5.3.1.1

Format for Group I Standards

Title - Standard Total Propulsion Plant
No. - TP-SG-etc.

1. Definition: This standard is a document which contains the technical information in standard format which is necessary to define and describe a _________ to ________ SHP steam turbine ________ feed heater propulsion plant. Standards are available for each of the following propulsion plants.

15,000 - 17,500 SHP	(2 Feed Heaters)
24,000 - 26,000 SHP	(2 Feed Heaters)
28,500 - 32,000 SHP	(4 Feed Heaters)
36,000 - 40,000 SHP	(4 Feed Heaters)
43,000 - 45,000 SHP	(4 Feed Heaters)
50,000 SHP	(4 Feed Heaters)

Standardized Parameters (for Total Steam Plant)

Steam Conditions @ Boiler Superheater Outlet

P: psig

T: ^{o}F

Main Condenser Vacuum: ________"HG

Sea Water Temperature: ^{o}F

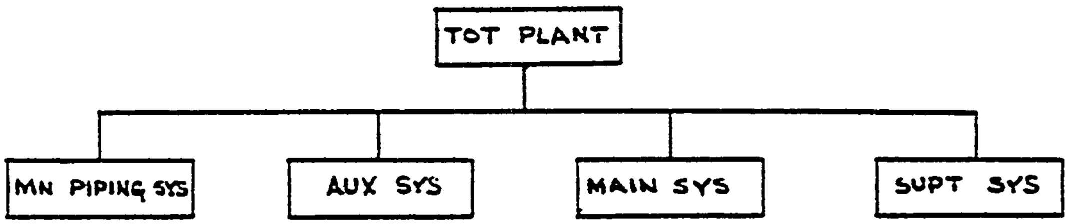
Outside Air Temperature: ^{o}F

Outside Air Relative Humidity: %

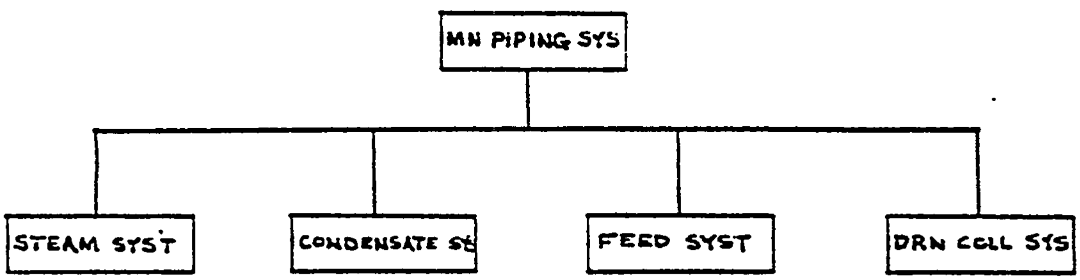
Machinery Space Air Temperature: ^{o}F

Machinery Space Air Relative Humidity: %

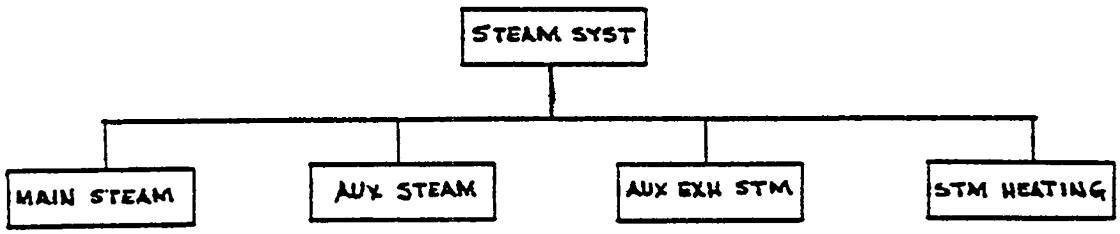
2. System Block Diagrams. The total plant for purposes of this Standard will consist of the following elements:



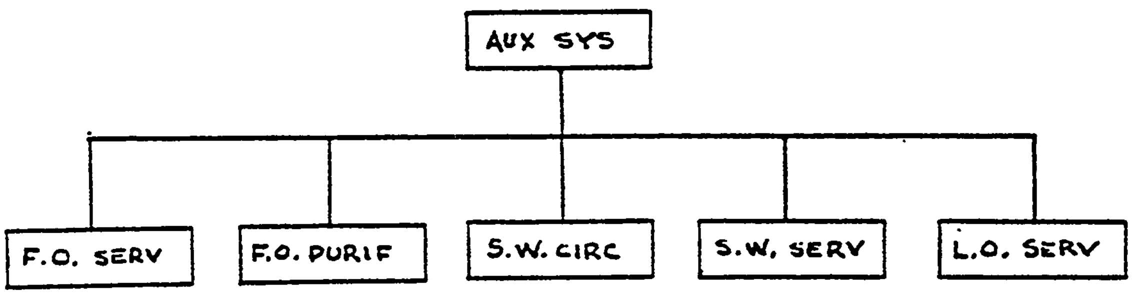
2.1 The Main Piping systems as pertain to this standard contain the following systems:



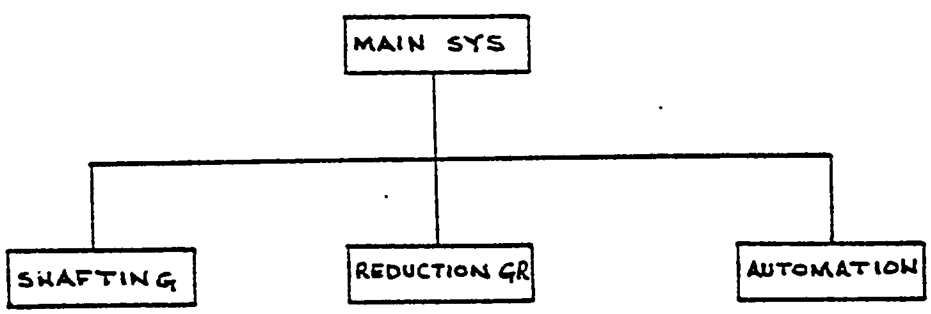
2.1.1 The steam systems segment of the main piping systems are further subdivided into the following main and auxiliary steam systems.



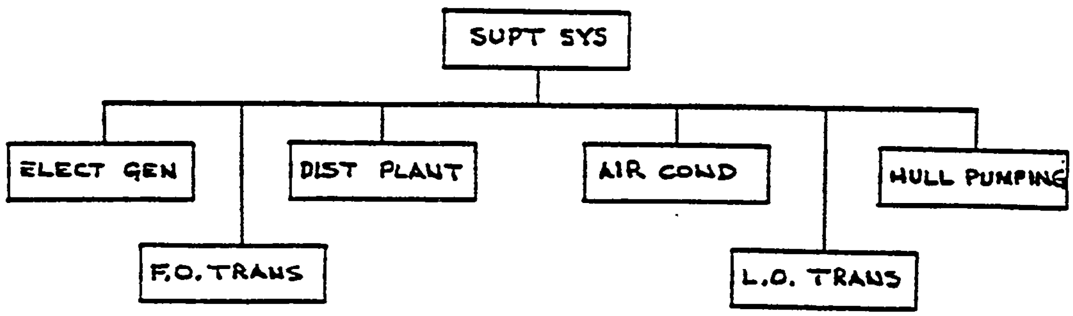
2.2 The Auxiliary Systems contain the following sub-systems which are required for operation of the propulsion system.



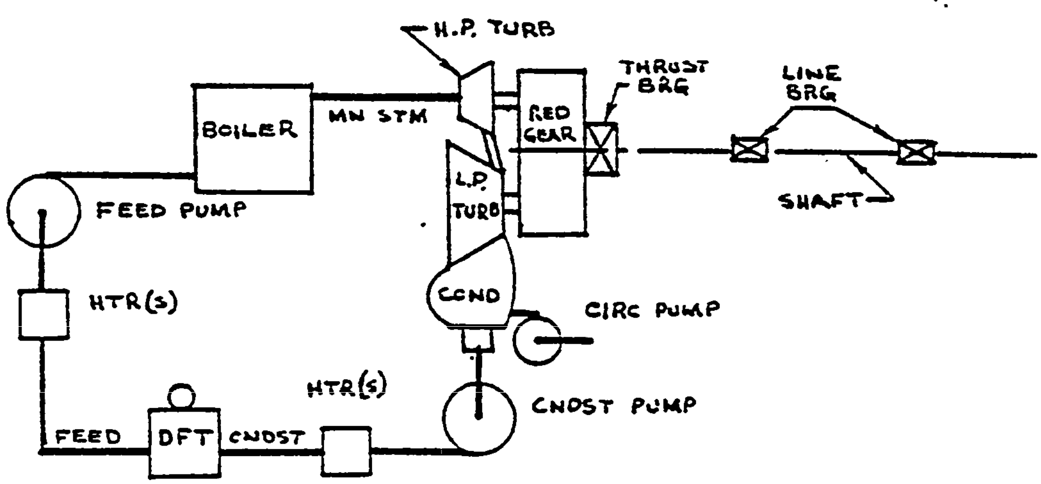
2.3 The main systems which are required for propulsion plants are contained in the following:



2.4 The Supporting Systems are those systems which are required for accomplishment of the ship's mission and which interface with and affect the propulsion system.



3. Propulsion Plant Block Diagram



4. Heat Balance Diagrams

Information required is compatible with that required for each system in paragraph 5, "System Diagrams." Heat Balance diagrams are prepared for the following conditions:

- Maximum Continuous Service
- Port Condition
- Operational Missions

4.1 Required data for heat balance diagrams

Refer to SNAME Technical & Research Bulletin 3-11

Steam Conditions (Press, Temperature, Enthalpy, Flow)

Water Conditions (Press, Temperature, Enthalpy, Flow) at inlets and outlets of all equipment in the propulsion plant loop

Condenser Vacuum

Ambient Air and Water Conditions (Press, Temperature, Humidity)

Boiler Efficiency

Boiler Fuel Rate

Turbine Steam Rate

Fuel Oil Conditions (Higher Heating Value)

Auxiliary Loads

Distilling Plant (Quantity and Efficiency)

Electric Load

Heating, Hot Water Loads

Air Conditioning Load

Equipment Operating Conditions (Working Pressures, Relief Pressures, System Losses, etc.)

Mission Requirements

Cargo Pump (Quantity, Type, Pressure, Temperature)

Crane Requirements (Electric, Fuel, etc.)

Tank Cleaning Requirements (Steam, Electric)

5. Systems Diagrams

Generally systems diagrams will be prepared for the following listed systems. Typically, each diagram consists of a one-line piping diagram showing the subject piping system with symbolic representations of all relevant equipment, valves, fittings, flanges, and instrumentation. Diameters of piping and sizes of fittings, and valves are indicated on the diagram. Included are Tables which list materials and specifications, maximum allowable fluid velocities, and equipment (pump) types, sizes and capabilities.

5.1 Steam Systems

- Main Steam
- Auxiliary Steam
- Auxiliary Exhaust
- Steam Heating

5.2 Condensate System

5.3 Feed System

5.4 Drain Collecting System(s)

. H.P. drains

. L.P. drains

5.5 Auxiliary Systems - These include all auxiliaries required for operation of the propulsion plant.

. Fuel Oil Service System

. Fuel Oil Purifier System

. S.W. Circulating System

. Auxiliary Condenser & S.W. Service Systems

. Lubricating Oil Service System(s)

5.6 Main Systems - These include the systems for major equipment allied with the main propulsion plant which is required for operation of the ship.

. Shafting System

Dimensional Diagram

Material Requirements

Bearing Type & Locations

Thrust Bearing (may be with Red Gr.)

Weight & Force Diagram

- Reduction Gear System

  Type

  Load Factors

  K Factors

  Gear Diagram

- Automation System

  Type System

  System Block Diagram

  One-Line Diagram

  Service Requirements

5.7 Supporting Systems -- These systems requirements are those which are required for proper sizing of components in the propulsion plant.

- Electric Generation

  Hotel Load

  Auxiliary Load

  Machinery Support Load

- Distilling Plant

  Required Load

  Efficiency

- Air Conditioning, Ventilation

  Required Load

- Hull Pumping Systems

  Bilge Pumping Diagram

  (Interfaces with Propulsion Systems)

  Ballast System Interface

  Fire-fighting System Interface

  Cargo Pumping Requirements (if applicable)
- Fuel Oil Transfer System
- Lubricating Oil Transfer System

6. A listing of available standards for equipment components and modules which may be used in the composition of this standard propulsion plant is included in Table D.

Table D

Equipment/Component	Standard No.	Standard Group	Remarks
Main Steam Boiler			
Main Turbine (Set)			
Main Condenser			
Reduction Gear (Set)			
Main Lube Oil Pump			
Forced Draft Fan			
Main Feed Pump			
Fuel Oil Service Pump			
Main Circulating Pump			
Main Condensate Pump			
Fuel Oil Heater			
Lube Oil Cooler			
First-Stage Feed Heater			
Gland Exhauster			
Drain Cooler			
De-aerating Feed Heater			
3rd Stage Heater			
4th Stage Heater			
Automation System			

STANDARD STEAM PROPULSION

PLANT DATA

24-26000 SHP

		TONNAGE RANGE
APPLICATION	TANKER	75-100000 DWT
	OBO	80,000 DWT

1. Main Boilers	(2)
Description:	2 Drum, single furnace, forced draft, water wall, air-heater, economizer, superheater, control desuperheater and steam atomizer type burners, automatic controls
Steam Conditions:	850 PSIG at 950° F.
Air Inlet Temp:	415° F.
Evap. (Capacity):	90000 #/HR - normal (each)
Efficiency:	88.5
Feed Water Temp:	415° F.
Specific Fuel:	.45 #/SHP/Hr
Size:	15' x 22' x 25'
Weight:	48 Tons (ea)
2. Main Turbine	One set
Description:	Cross-compound,impulse, single flow, astern element in L.P. Turbine
Output:	26000 SHP
Turbine RPM	H.P. - 5600, L.P. - 3600
Steam Conditions:	850 PSIG, 950° F.
No. Extractions:	2
Size:	H.P. - 6' x 15' x 10', L.P. - 10' x 28' x 15'
Weight:	26 Tons (combined)
3. Main Condenser	(1)
Description:	Shell and straight tube, single pass, surface type, with reheating and deaerating hot well
Surface:	22,500 Ft^2
Capacity:	120,000 #/HR
Vacuum:	28.3" Hg
Cooling Water:	35,000 GPM at 6.0 Fps
Tube Diameter & Thick:	3/4" x 18 BWG
Material - Sheet, Plate, Sep:	90-10 Copper-Nickel Alloy
Size:	26' x 10' x 14'
Weight:	55 Tons

4. Reduction Gear	1 Set
Description:	Double reduction, articulated, attached lube oil pumps, twin pinion
*Rating:	26,000 SHP at 90 RPM
*"K" Factors:	1st - 140, 2nd - 110
Size:	8' x 26' x 18'
Weight:	60 Tons
*Note: May Vary by Ship Type	
5. Main Lube Oil Pump	(2)
Description:	Vertical, rotary, sump type, motor driven
Capacity:	500 GPM
Head:	60 PSI
RPM:	1200
6. Forced Draft Fans	(2)
Description:	Horizontal, centrifugal, cross-connected, motor driven
Capacity:	40000 CFM
Static Pres:	17" Hg
7. Main Feed Pumps	(2)
Description:	Horizontal, centrifugal, multi-stage, steam turbine driven
Capacity:	500 GPM
Head:	1200 PSI
8. Fuel Oil Service Pumps	(2)
Description:	Horizontal, rotary, motor driven
Capacity:	40 GPM
Head:	350 PSI

9. Main Circulating Pumps		(2)
	Description:	Vertical, single stage, centrifugal, 2-speed, motor driven
	Capacity:	24000 GPM
	Head:	20 Ft
10. Main Condensate Pumps		(2)
	Description:	Vertical, 2-stage, centrifugal, motor driven
	Capacity:	350 GPM
	Head:	250 Ft
11. Fuel Oil Heaters		(2)
	Description:	Extended surface, horizontal, shell and finned tube
	Capacity:	17,500 #/HR (each)
	Inlet T.:	100° F.
	Outlet T.:	250° F.
	Steam Pres:	150 PSI
12. Lube Oil Coolers		(2)
	Description:	Horizontal, shell 2-pass, U-tube
	Surface:	600 Ft^2
	Inlet T.:	140° F.
	Outlet T.:	120° F
	Sea Water Temp:	85° F at 6 fps
	Material:	90-10 Cu-N - Tubes & Baffles
13. Feed Water Heater-Combination 1st stage feed heater, gland exhaust comp. & drain cooler		(1)
	Description:	Closed, horizontal, multipass shell and tube
	Capacity:	175,000 #/HR
	Outlet T.:	220° F

14. Deaerating Feed Heater	(1)
Description:	Vertical, direct contact, spray type
Capacity:	200,000 #/HR
Outlet T.:	285° F.

STANDARD DIESEL PROPULSION - PLANT DATA

12 - 14000 SHP

Application		Tonnage Range
	TANKER	25 - 35000 DWT
	BULK/ GEN CARGO	25000 DWT

1.	Main Engines	(2)
	Description:	4-cycle, V-16, Marine, Turbo-charged, Dual Fuel, Pneumatically Coupled.
	Rating:	7000 BHP at 400 RPM
	Bore/Stroke:	17" x 21"
	BMEP:	182 psi
	Size:	23' x 14' x 16'
	Weight:	115 Tons
2.	Controls	
	Type:	Automatic centralized control; remote engine, propeller and auxiliary control, automatic instrument monitoring and recording
	Classification:	Manned, ACC-ABS Certification
	Equipment:	Data, bell and alarm loggers, mimic panel, automatic and manual control modes, digital display, constant readout gages, control logic and memory unit
	Location:	Main control - Engine Room Secondary Control - Bridge
3.	Compressed Air System	
	Compressor Description:	Two, 2-stage, 2 cyl., motor driven, automatic
	Capacity:	125 CFM
	Pressure:	600 PSI
	RPM:	1000
4.	Exhaust Gas Boilers (2)	
	Description:	Horizontal, water tube, single gas pass, waste heat recovery
	Capacity:	2500 #/HR
	Pressure:	150 PSI
	Temperature:	250° F.
5.	M. E. Fresh Water Coolers (3)	
	Description:	Horizontal, single-pass, straight tube, raw water
	Surface:	500+ Ft^2
	Outlet T.:	200° F.

6. M.E. Lube Oil Coolers (2)

Description:	Horizontal, 2-pass, U-tube, raw water
Surface:	250 Ft^2
Outlet T.:	200° F.

7. Fuel Oil Heaters (2)

Description:	Horizontal, 2-Pass, U-Tube, Steam
Surface:	125 Ft^2
Temp.:	200° F.

8. Fuel Oil Purifier (1)

Description:	Centrifugal, automatic, motor driven
Capacity:	450 GPH
Heater:	18 KW

9. Lube Oil Purifier (1)

Description:	Centrifugal, automatic, motor driven
Capacity:	350 GPH
Heater:	25 KW

10. Fuel Oil Booster Pumps (2)

Description:	Vertical, centifugal, motor driven
Capacity:	40 GPM
Head:	60 PSI

11. M. E. Lube Oil Pumps (4)

Description:	Vertical, centrifugal, motor sump type
Capacity:	600 GPM
Head:	75 PSI

12. M.E. Cooling Water Pumps (2)

Description:	Horizontal, centrifugal, motor driven
Capacity:	1500 GPM
Head:	40 PSI

13. Main Salt Water Pumps (2)

Description:	Horizontal, centrifugal, motor driven
Capacity:	2650 GPM
Head:	50 Ft

14. Reduction Gear (1)

Description:	Single reduction, double helical, twin pinion, reversible, clutch-connected (pneumatic)
Rating:	14000 BHP at 90 RPM
Gear Ratio:	4.451/1.0

15. Reduction Gear Lube Oil-Pump - Booster (1)

Description:	Vertical, rotary, motor driven, single stage
Capacity:	125 GPM
Head:	75 PSI

4.5.3.2 GROUP II Equipment/System Module Standards

Definition:

These standards are documents which contain the technical data and information required to define and describe a complete sub-system or group of like equipment which is mounted together on a common base. This module has defined and located interfaces and limiting size dimensions and weights, which make the modules (but not the components) interchangeable from all sources. The equipment which is included in the module may or may not be standard.

These standards afford the benefits of standardized equipment without limitations being imposed on equipment vendors.

The equipment/systems which lend themselves to being packaged together on skids are:

F.O. Service System

L.O. Service System

L.O. Purifying System

Power Unit

H.P. Feed Heaters Module

Feed Pump Module

Condensate Pump Module

Diesel Accessory Racks

Diesel Starting Package

In order to illustrate this standard, an example of a fuel oil service system module format follows:

4.5.3.2.1

. Example: First Page

Identification: Alpha-numerical standard identification with encoded type and size.

Application: General data with reference to the scope of this standard as to sizes, temperatures, pressures, and medium characteristics.

Next Page(s)

<u>Performance Data Matrix</u>: Chart showing capacity, pressure, temperature and viscosity characteristics 'for each module.

Next Page(s)

<u>Outline Drawing(s)</u>: Drawings plus dimension chart giving interface sizes and locations, mounting information and overall size and weight limitations for each module.

Next Page(s)

<u>Design Characteristics</u>: Contains listing of components required with technical data requirements of each component. Includes block and/or schematic diagram of **system.**

<u>Approvals</u>: Includes regulatory agency approvals of module designs.

<u>Equipment Suppliers</u>: Includes the following lists with approvals noted if applicable.

1. Module manufacturers
2. Individual component manufacturers

<u>Other Documents</u>: Reference to other standards and specifications which are applicable.

4.5.3.2.2 On the following pages, basic definitions and descriptions of above modules are given. The parameters for Standardization at the module level can be picked from these descriptions. Of the modules listed above, the follcwing three will be economically analyzed in Subtask 3:

1. F.O. Service System Module
2. Main Feed Pump Module
3. Diesel Accessory Rack Module

4.5.3.2.1 <u>The F.O. Service *System* Module</u>

The fuel oil service system module contains the following:

- 2 fuel oil service pumps
- 2 fuel oil heaters
- 2 strainers (suction and discharge)
- flow meters
- control panel
- associated valves, piping and fittings
- Pressure regulating station

The equipment is interconnected with pre-formed pipe and tube assemblies and all connections are pre-fitted and aligned at the time of manufacture or assembly of the module. The system is cleaned and leak tested at the assembling activity.

Enough space is provided within the module to allow easy access for operation and maintenance.

The foundation is pre-drilled for easy bolting; and the piping connections - both steam and oil - are led to the appropriate location on the imaginary cube for quick connection of interface piping during installation.

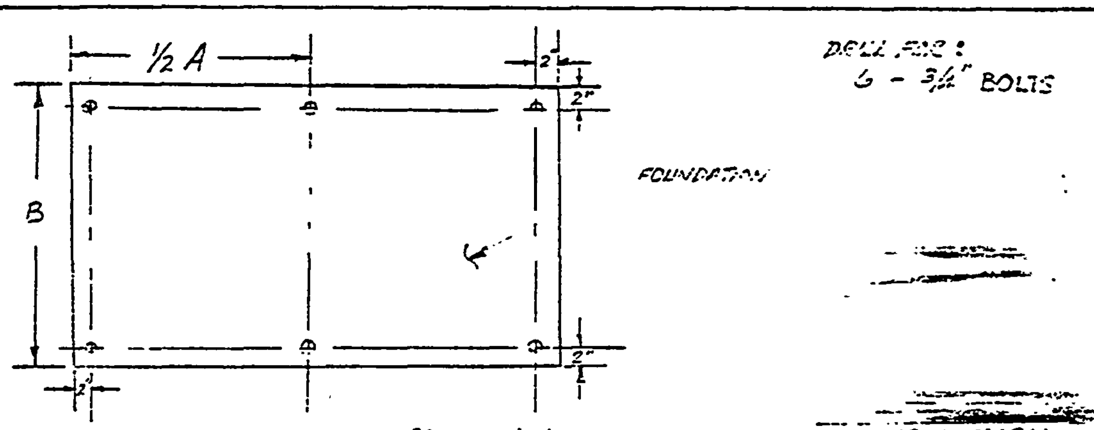


figure 4-4

The fuel oil service system module is defined as to its equipment arrangement, dimensions, weight and interface piping connections in the following illustrations:

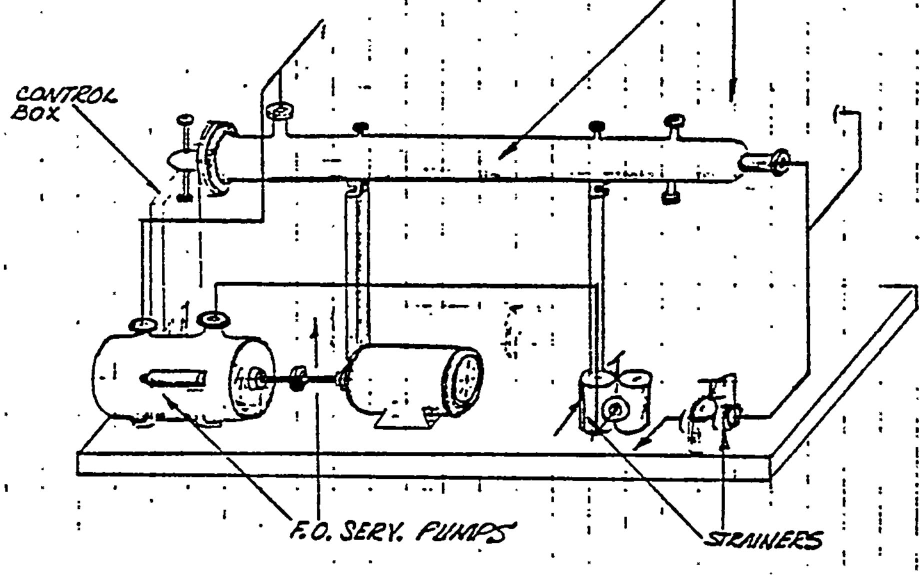


Figure 4-5 F.O. SERVICE SYS. MODULE

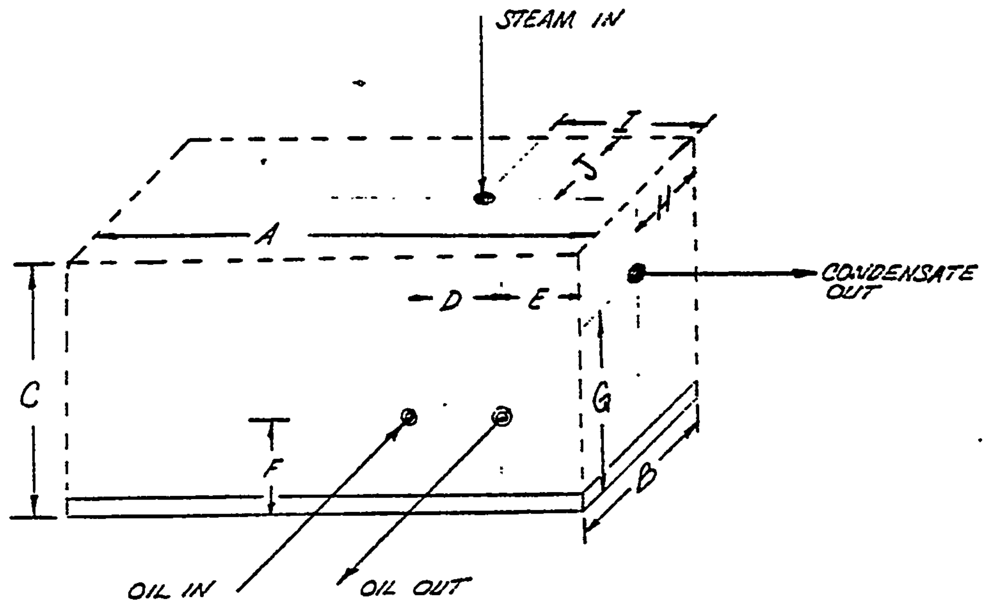


Figure 4 - 6 F.O. SERVICE SKID ENVELOPE

Table 4-14 MODULE DIMENSIONS

	SHP	A	B	C	D	E	F	G	H	I	J
A	15000-26000	10.5'	5'	8'	2'	1.5'	1.5'	4.5'	2.5'	3.5'	1.25'
B	28500-40000	11'	5'	8.5'	2'	1.5'	1.5'	4.5'	2.5'	3.5'	2.0'
C	43000-50000	12'	5'	8.5'	2'	1.5'	1.5'	4.5'	2.5'	3.5'	2.0'

Table 4-15
INTERFACE CONNECTIONS SIZES

SIZE	OIL CONN	STEAM CONN	COND. OUTLET
A	2-3"	2-2½"	2"
B	2-3"	3"	2½"
C	2-3"	3"	2½"

Table 4-16
MODULE WEIGHT TOTAL

SIZE	WEIGHT
A	3156#
B	3434#
C	3834#

The sizing of the strainers, flow meters and pressure regulating station is determined by the capacity of the fuel oil system. This capacity is defined by the capacity of the fuel oil heaters and fuel oil service pumps which, in turn, is determined by the fuel oil demand of the boilers.

All heaters will be shell and tube type receiving steam at 100 psig and 350°F to raise the fuel oil from 120°F to 240°F. Their capacity per shaft horsepower is listed below:

- 15,000 SHP - 8,500 #/hr ea
- 17,500 SHP - 8,750 #/hr ea
- 24,000 SHP - 13,500 #/hr ea
- 26,000 SHP - 15,000 #/hr ea
- 28,500 SHP - 16,500 #/hr ea
- 32,000 SHP - 18,500 #/hr ea
- 40,000 SHP - 23,000 #/hr ea
- 43,000 SHP - 24,500 #/hr ea
- 45,000 SHP - 25,750 #/hr ea
- 50,000 SHP - 28,500 #/hr ea

The fuel oil service pumps will be horizontal, rotary, motor-driven pumps with ratings at 350 psig per shaft horsepower are listed below:

- 15,000 SHP - 20 gpm ea
- 17,500 SHP - 25 gpm ea
- 24,000 SHP - 32 gpm ea
- 26,000 SHP - 40 gpm ea
- 28,500 SHP - 45 gpm ea
- 32,000 SHP - 50 gpm ea
- 40,000 SHP - 60 gpm ea
- 43,000 SHP - 65 gpm ea
- 45,000 SHP - 70 gpm ea
- 50,000 SHP - 75 gpm ea

The fuel oi1 service suction and discharge strainers, mounted on the skid, will be duplex mesh strainers.

The flow meters will be installed between the fuel oil service pumps and fuel oil heaters and mounted for easy inspection. They will be provided with a by-pass to allow removal for inspection and repairs without creating discontinuity of fuel supply to the boilers. The meters will be the oscillating disc type.

The control panel contains the electrical control circuits for manual start-stop operation of the fuel oil pumps and indicating lights.

The pressure regulating station is located between the service pumps' discharge and the burner header (after the fuel oil heaters), to provide constant pressure at the inlet side of the burner headers by recirculating oil back to the pump suction.

4.5.3.2.2 The L.O. Purifying System Module

The L.O. purifying system contains the following:

- L.O. Purifier
- L.O. Heater
- L.O. Stripping Hand Pump
- L.O. Sludge Tank
- Simplex Strainer
- Pressure Gage and Thermometer
- Associated Valves, Piping and Fittings

The equipment is interconnected with pre-formed pipe and tube assemblies and all connections are prefitted and aligned at the time of manufacture or assembly of the module. The system is cleaned and leak tested at the assembling activity.

To allow easy access for machinery operation and maintenance enough space is provided within the module.

The foundation is pre-drilled for easy bolting, and the piping connections for steam, hot water and oil are installed to the appropriate location on the imaginary cube for quick connection of interface piping during installation.

Lubricating oil purifier heater is of bayonet tube type. In this tubular heater, oil enters the shell of the heater at the tube sheet and is directed by a system of segmental baffles to flow back and forth across the tube bundles. Bayonet tube is shown in Figure 4-7.

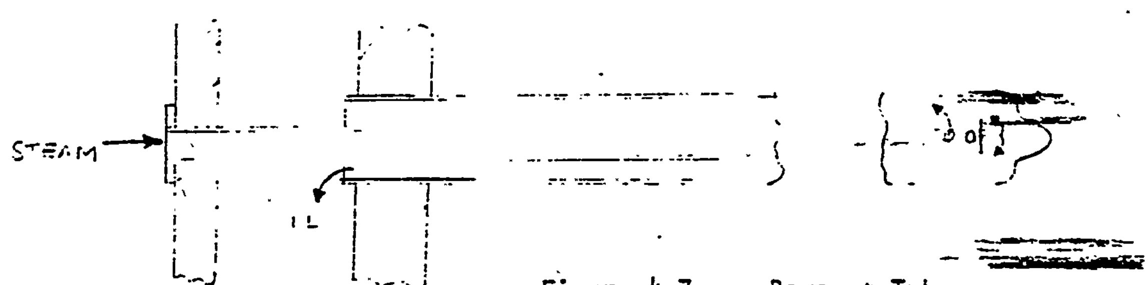
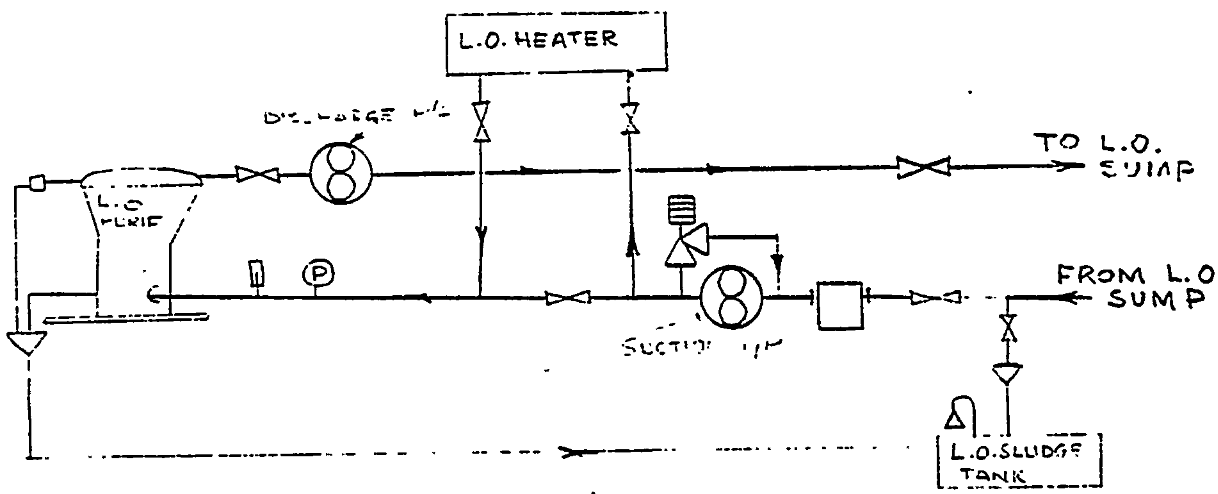


Figure 4-7 - Bayonet Tube

In L. O. purifier, heater oil must be heated to a range of 100 to 160° F. in order to obtain a sufficiently low oil viscosity for effective purification. The steam supply pressure is 45 PSIG. For a typical 24000 SHP steam turbine propulsion system, L.O. heater capacity is 350 GPH, and clean-tube factor is 80%

Self cleaning L. O. purifier is of centrifugal type. Capacity of a typical 24000 SHP steam propulsion system purifier is 350 GPH. Pump discharge pressure is 40 PSIG and motor is of 2 H.P. and 1730 RPM. All pumps have as standard a by-pass valve and the suction pump is equipped with an easily removable strainer. The pumps are of rotary gear type.

Lubricating oil purifying system is shown in Figure 2.



LEGEND OF SYMBOLS:

- Stop Valve
- Pressure Gage
- Thermometer
- Simplex Strainer
- Funnel

Figure 4-8 L.O. PUR. SYS. DIAGRAMMATIC

4.5.3.2.3 The L.O. Service System Module

The lubricating oil service system module contains the L.O. strainer and the L.O. coolers. The L.O. service pumps are normally located on the L.O. pump. The strainer and coolers are unitized on a platform and can be located near the service pumps by being attached to the reduction gear casing or they can be installed separately.

The module (coolers and strainer) is fully assembled on a foundation with interconnecting valves, piping and fittings being led to the interface locations on the imaginary cube. This system is cleaned and leak tested at the assembling activity.

The foundation is pre-drilled for easy bolting at the time of installation.

The module would be arranged as illustrated in the following sketch:

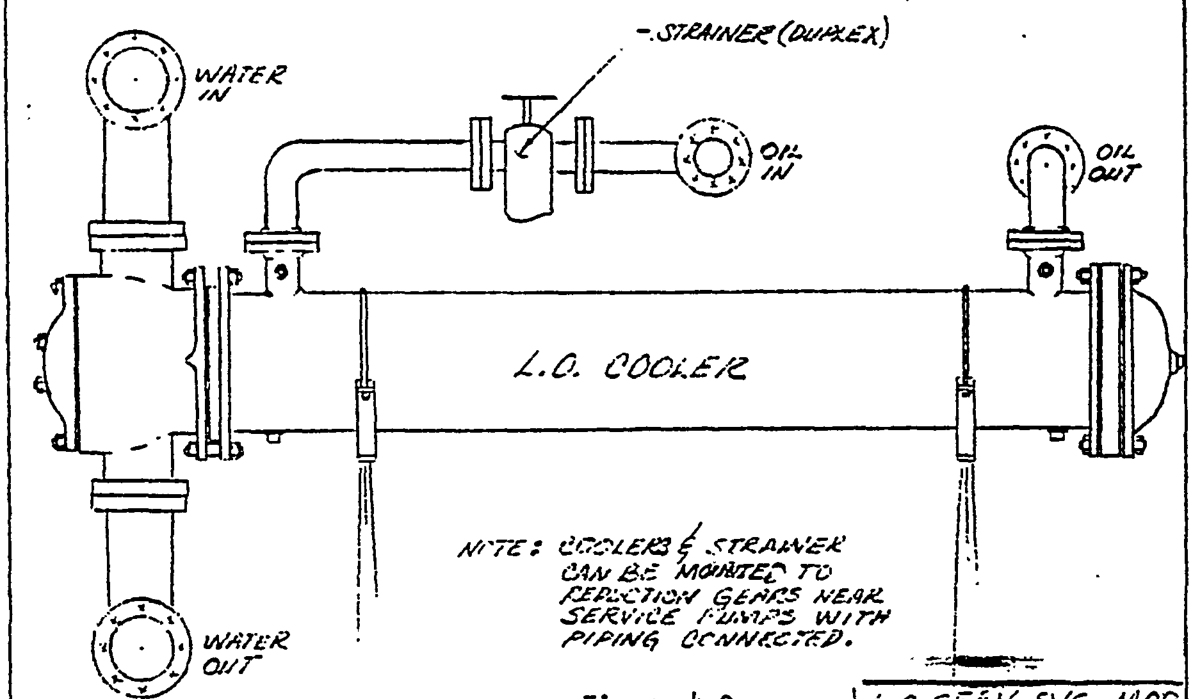


Figure 4-9

The lube Uoil cooler is a shell and straight tube type cooler with a floating tube sheet. "The tubes may be the finned type to increase heat transfer. .Baffles may be segmented counterflow or the orifice type.

The cooler is designed *to cool* the oil at full power operation, at maximum sea water temperature and maximum tube fouling and at a capacity determined by the lube oil pump rating.

The two lubricating oil pumps are each capable of meeting 125%. of the requirements of L.O. flow recommended by the appropriate manufacturers at maximum power conditions. They are either centrifugal or positive-displacement, vertical, submerged, motor-driven pumps located on and in the lube oil pump at the reduction gear casing. The second pump acts as a stand-by pump to cut-in when the main pump loses discharge pressure. Both pumps are arranged for power take-off from the emergency generator; in cast the main generator fails, the emergency generator is started automatically and provides continuity of electric power.

The strainers are duplex and are installed between the pumps and the lube oil coolers. The strainer switching valves are so arranged as to provide continuity in lube oil flow while maintaining one basket.

4.5.3.2.4 The Power Unit Module

The power unit module contains the following:

- 1 main high pressure steam propulsion turbine
- 1 main low pressure steam propulsion turbine
- 1 main condenser
- 1 air ejector with air ejector condenser
- turbine controls
- foundation and supports
- associated valves, piping and fittings

The high pressure turbine is supported by longitudinal girders while the low pressure turbine is supported by the athwartship condenser.

The low pressure turbine exhaust with a down-flow exhaust to the main condenser.

The control system includes:

- a hydraulic pump
- a throttle input and feedback mechanism
- control electronics
- an input processing board
- a position control board
- a speed feedback board
- an automatic rollover board
- an overspeed governing board
- a malfunction proportional control
- a test panel
- a control power supply

- a relay lagic circuit
- a turbine trip
- a turning gear interlock
- alarms
- maneuvering valves

Great care must be taken in respect to foundation supports and alignment with the reduction gears. In fact, the reduction gears should be supplied via the module supplier to assure proper alignment. The gears could be shipped at the same time as the module.

The general arrangement of such a module could be as illustrated in the following sketches:

Downflow Exhaust; Articulated Gearing

In this arrangement, the high-pressure turbine is supported on longitudinal girders, and the low-pressure turbine is mounted on an athwartship condenser. The turbines drive the low-speed shaft through an articulated type, double helical, double reduction gear.

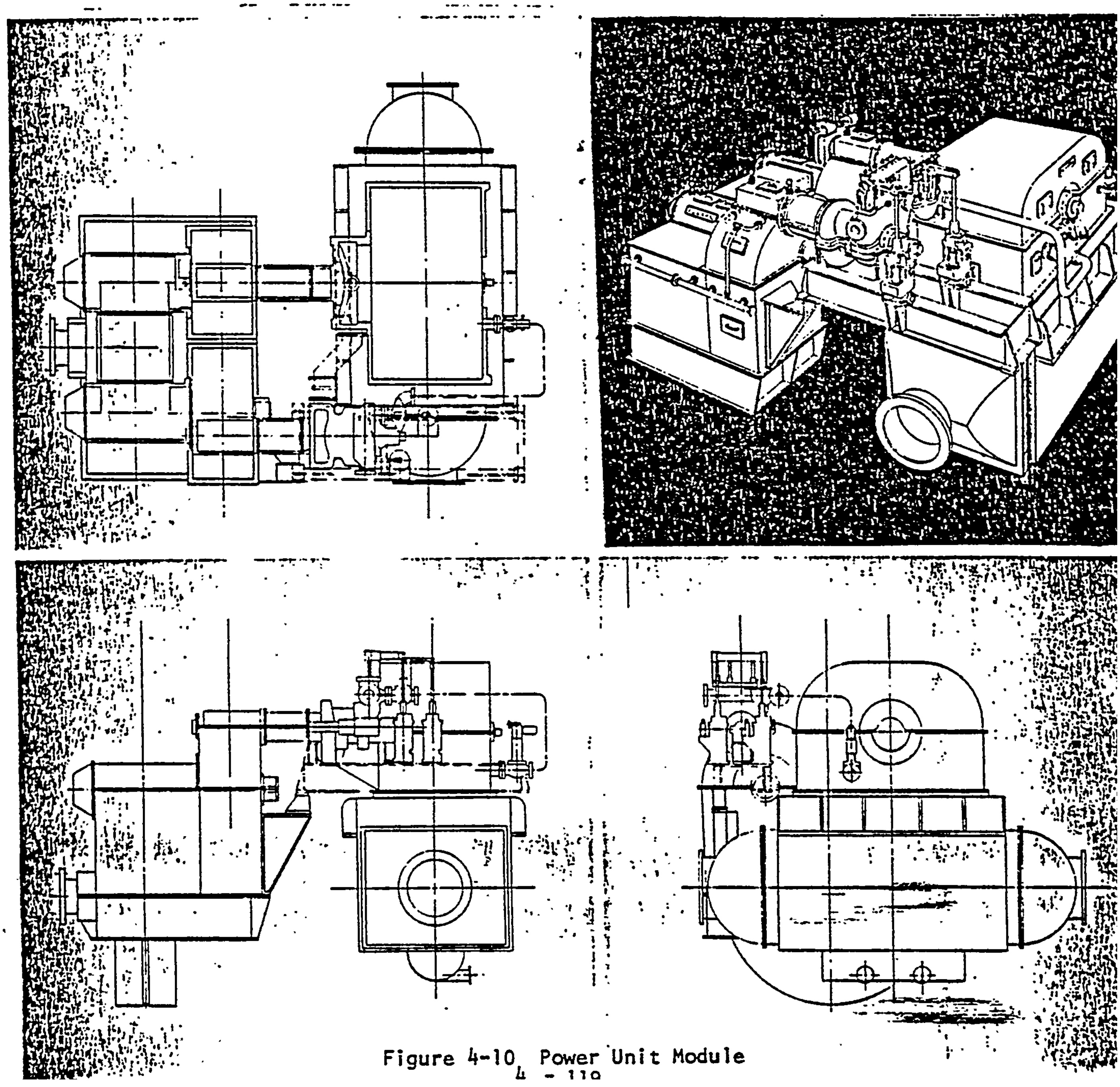


Figure 4-10 Power Unit Module

4.5.3.2.5 The Feed Pump Module

The feed pump module contains the following:

- 2 main feed pumps
- 1 in-port feed pump
- controls
- associated piping, valves and fittings
- feed pump governors

The above listed equipment is mounted on one foundation held in place by bolting, hangers and structural supports. The machinery is aligned and piped to interface locations at the time of assembly. All piping and machinery are cleaned and leak tested before shipment.

The main feed pumps are horizontal, centrifugal, multi-stage, turbine-driven pumps. They are sized such that each pump, singularly, can develop the required pressure and capacity of feed to both boilers under maximum power conditions.

The in-port feed pump is a variable stroke, positive displacement, motor-driven pump.

The controls are as follows:

- automatic stand-by main feed pump start
- manual and automatic start-stop operation of the in-port feed pump.

Each feed pump is provided with a stop-check valve at its discharge and a suction isolation valve with crossovers between suctions and discharges on all pumps.

The governor controls on the main feed pumps are either of the constand-pressure or the differential-pressure type.

4.5.3.2.6 The H.P. Feed Heaters Module

It is general practice to combine the first stage feed heater with the gland exhaust condenser and the drain cooler (or atmosphere drain tank).

The D. C. (Direct Contact) Heater (or deaerating feed heater), is located quite high in the engine room to provide adequate suction head to the main feed pumps thus preventing the high temperature feed water from flashing to steam during the pumping process. Therefore, the D. C. heater cannot be combined with any of the other feed heaters.

The third and fourth stage heaters lend themselves to being combined on a common foundation since they are exactly alike and this location is flexible. The fourth stage heater is fixed to a foundation and in turn supports the third stage heater.

All associated valves, flanges, piping, gauges, lagging, etc. are assembled with the heaters during production. The steam piping into the third and fourth stage heater, the feed piping to the third stage heater, and the feed piping from the fourth stage heater are led to the interface locations on the imaginary envelope surrounding the feed heaters.

All equipment, piping, fittings, etc. an cleaned and hydrostatically tested before shipping. The foundation is pre-drilled for easy bolting at the time of installation.

The module would be arranged as illustrated in the following sketch:

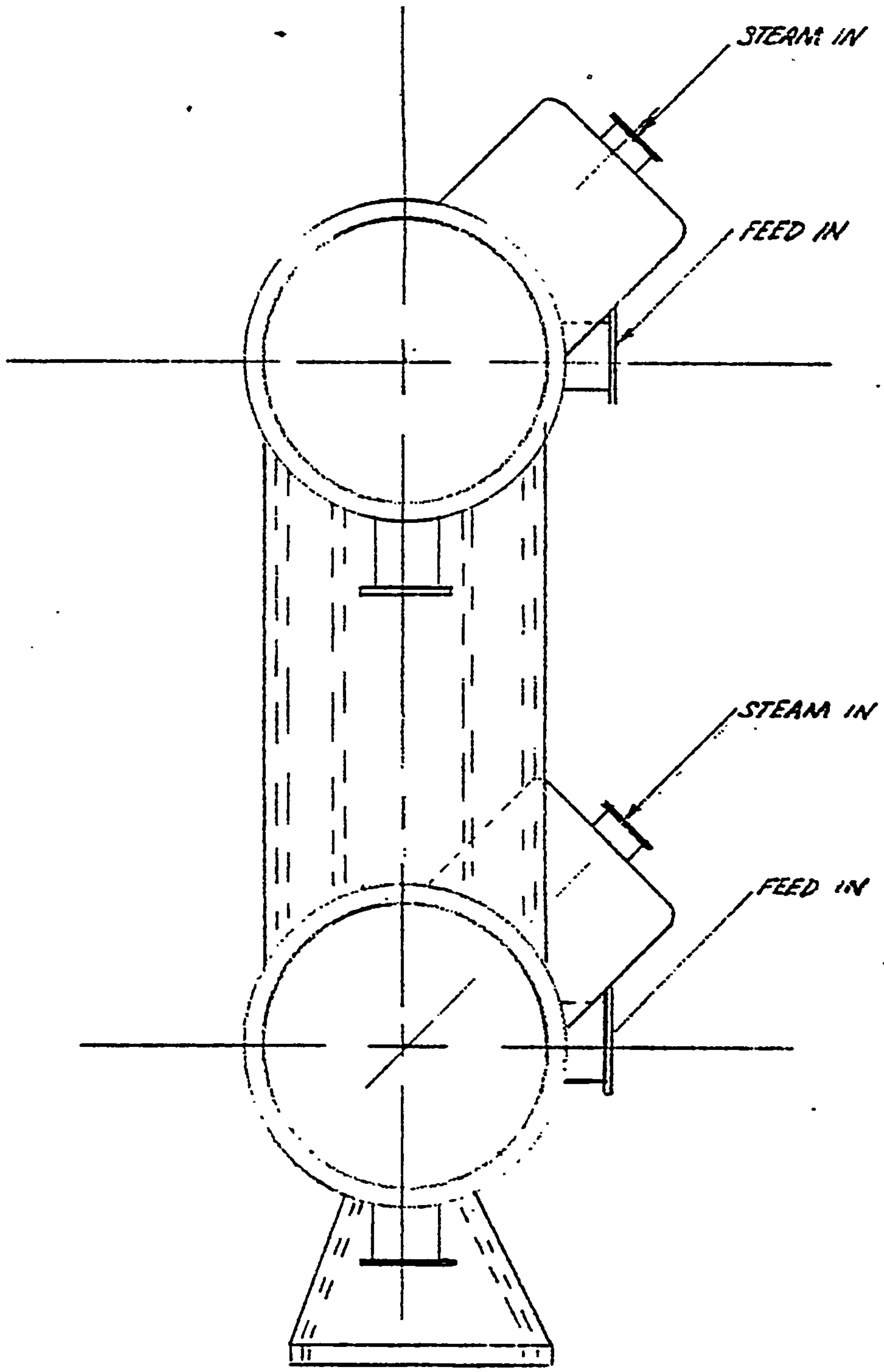


Figure 4-11
TYPICAL COMBINED 3RD & 4TH STGE. HTRS.

The third and fourth stage feed heaters are high pressure feed heaters in a horizontal attitude to provide a higher condensing heat transfer coefficient, less reheat problems and a smaller shell diameter.

The heaters are shell and tube type heaters with integral sections.

The heaters capacities are based upon the full power heat balance.

4.5.3.2.7 The Condensate Pump Module

The main condensate pump module contains two main condensate pumps, their motor drives and the associated vaives, fittings, piping and controls.

The main condensate pumps are vertical, centrifugal, single suction, motor-driven pumps. Each pump's and capacity is based on 15% in excess of the requirements of condensate flow under maximum power conditions. The rated head is based on static head to the deaerating feed tank feed inlet, valve, piping and heater losses, the operating steam pressure in the deaerater and the condenser vacuum at the rated capacity of the pump.

The associated valves, piping and fittings include separate suctions, separate-to-combined discharges, crossovers, seals piping, vent piping, butterfly suction valves, and stop-check discharge valves.

The controls are:

- manual start-stop
- standby cut-in
- pump alternation

Al 1 equipment are mounted by bolting on one foundation with the proper hangers and supports. The machinery, piping, valves and motors are pre-aligned ; and they are cleaned and leak-tested prior to shipment. The piping is led to the standard interface locations on the imaginary envelope surrounding the module.

4.5.3.2.8 The Diesel Accessory Rack Modu1 e

The diesel accessory rack module is an assembly of diesel engine associated accessories in a unitized module. It contains the following components:

L.O. Filter

L.O. Cooler

Fuel Priming Pump

Fuel Strainer

Water Expansion Tank

Cooling Sys. Thermostatic Valve

Raw Water Pump

Engine Control Panel

Associated valves, piping and fittings.

The above components are interconnected with pre-formed pipe and tube assemblies. The lube oil and jacket water systems are cleaned and tested at the factory.

The components are mounted on foundations and arranged with aedquate space for easy access for maintenance and operation.

The foundation is pre-drilled for easy bolting and the module is easily connected to the engine by bolting together five flanged connections (three for cooling water and two for lubricating oil) and the connecting of four tube connections (two gauge lines and two fuel lines). They are pre-fitted and aligned at the time of manufactufie.

The arrangement of the accessory rack module is as illustrated in the following sketch:

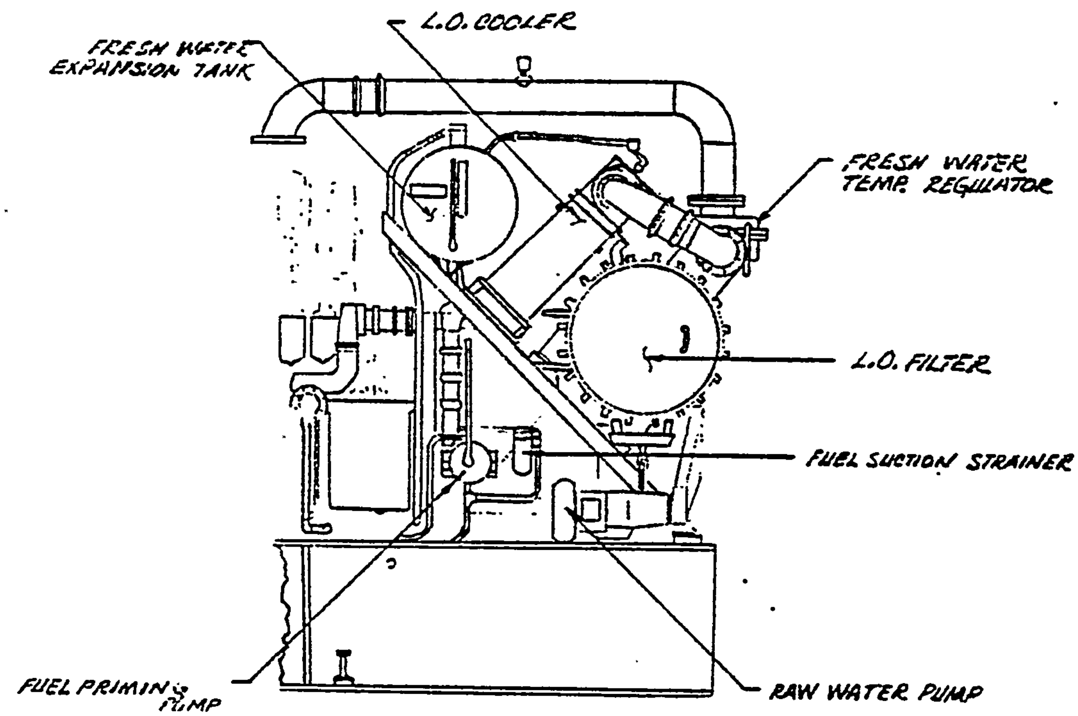


Figure 4-12
DIESEL ACCESSORY RACK

There are two types of lube oil filters. They are the seven (7) element filter and the fourteen (14) element filter. The capacity (or number of elements) is dependent upon the size and number of cylinders the engine has. Below 16 cylinders uses the seven element filter and 16-20 cylinder engines use the fourteen element filter.

The full-flow filter assembly contains 15 micron replaceable pleated paper filter elements and a 160# oil inlet pressure gauge.

The lube oil cooler is a fin/tube type with seven psi by-pass valves built in to permit oil to bypass the cooler under excessive pressure. A high oil temperature alarm contactor is also provided.

The fuel priming pump is manually operated to circulate oil to the fuel filters and fuel injectors before starting the engine after extended shutdowns.

The fuel suction strainer is located between the fuel supply and the fuel pump to remove contaminants through an 80-mesh, pleated, metal strainer.

The fresh water expansion tank is approximately 85 gallons in size. It is provided with a sight glass, filler opening, overfill drain line and a pressure cap. The pressure cap is designed to open if excessive pressure occurs.

The cooling system thermostatic valve consists of a regulator valve and a thermostatic control element which senses the cooling water temperature causing the regulator valve to open or close, thereby regulating temperature.

The. raw water pump is used to circulate raw water through.a cooler to lower the temperature of the engine fresh *water* supply. It is a horizontal, centrifugal, belt-driven (off the accessory end of the engine), type motor.

The engine control panel uses 115 volt AC, 60 cycle voltage; it is drip-proof, and it includes local controls and alarm indicators for manual operation. It includes the following gauges:

- L.O. pressure
- F.O. pressure
- Starting air pressure
- Clutch air pressure
- Raw water pressure

It includes the following indicators, switches and warning lights:

Engine speed electrical tachometer	- Overspeed tripped light
Engine start and stop *switches*	- High oil temperature light
Test and alarm silence switches	- Low lube oil level light
Alarm reset switch	- Power on light
Power on and off switches	- Engine air filter light
Hot engine light	- Vacuum light
Low oil pressure light	- Low clutch air pressure ligh
High crankcase pressure light	- Low turbo oi1 pressure light

Appropriate alarms contractors are supplied for installation by the shipyard.

Located on the side of the control panel is an engine exhaust pyrometer and *selector* switch, with a temperature range of 0-1200° F.

All associated interconnecting valves, piping and fittings are provided and led to the interfacing points on the imaginary envelope.

4.5.3.2.9 The Diesel Air Starting Package

The diesel air starting module contains the following:

- Air tanks
- Air compressor
- Shut-off valve
- Air-relay valve
- Lubricator
- Solenoid air valve
- Pressure relief valves
- Associated piping and fittings
- Controls

The above mentioned equipment, valves, piping and fittings are mounted on foundation with enough space allotted for easy maintenance and operation. The system is assembled, a ligned, cleaned and leak-tested prior to shipment. The foundation is pre-drilled for easy bolting aboard ship.

The air compressors are motor-driven, two stage air cooled, single acting units designed with intermittent duty. Each compressor is equipped with an intercooler, v-belt drive, intake filter, automatic unloader, and an automatic start-stop control. They develop 600 psi air pressure. The compressors are sized to be capable of fully charging the air tanks in 60 minutes.

The starting air tanks are vertical metal tanks fitted with a relief valve and a drain valve. The relief valves are set at 615 psi. The number of tanks and their capacity are determined by ABS rules which requires enough air capacity as to provide 12 starts without recharging the teaks.

TYPICAL STARTING AIR SYSTEM

ENGINE–GEAR UNIT WITH BASE

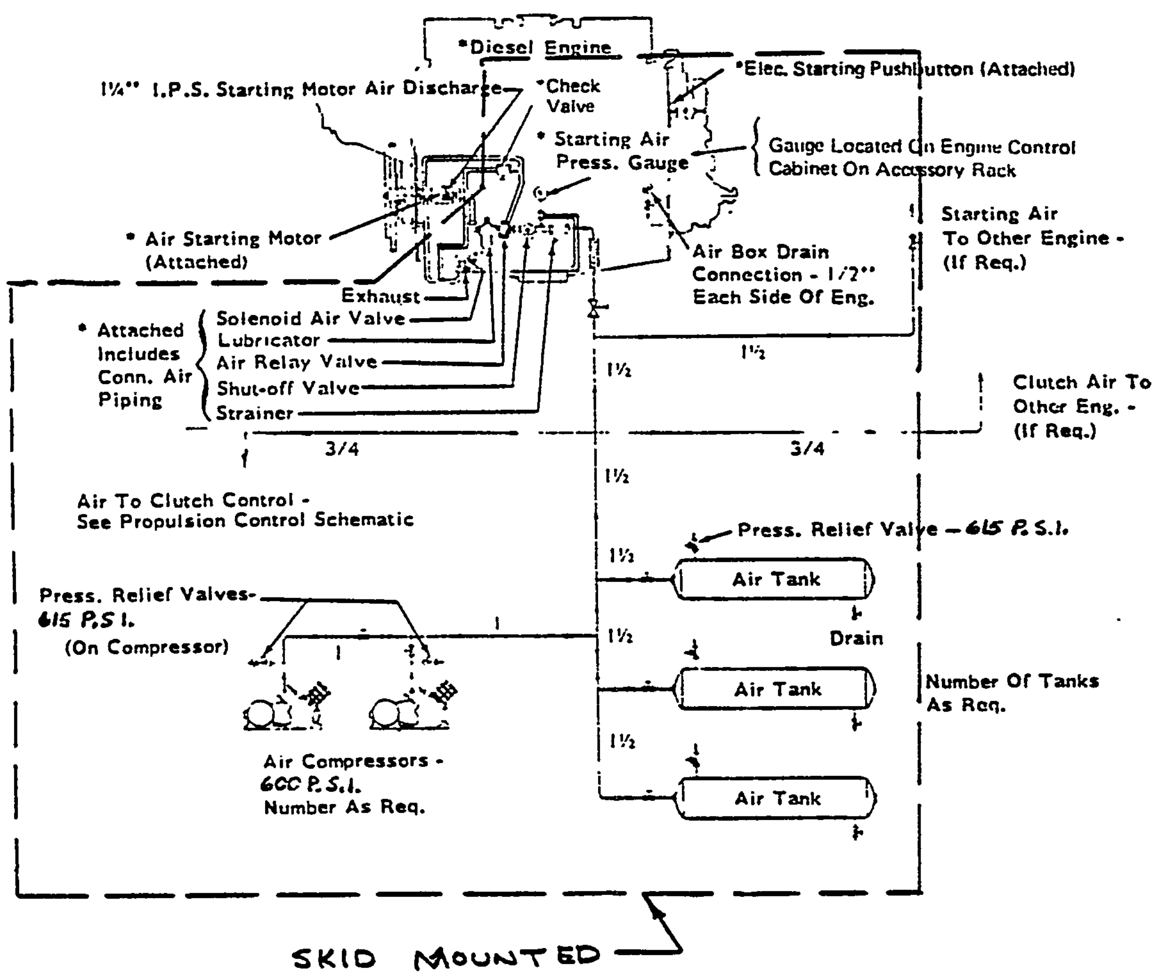


Figure 4-13

STARTING AIR SYS. DIAGRAMMATIC

4.5.3.3 GROUP III Equipment Envelopes Standards

These standards are documents which contain the technical data and information in standard format which is required to define and describe the interface characteristics of equipment so that separate vendors equipment of like characteristics may be used interchangeably. The envelope standard concept limits overall size and weight of the envelope and determines interface and installation requirement sizes and locations for that particular equipment independent of vendor source. These data will be such that all eligible vendors will be able to meet the requirements of the standard by using a sub-base and adding interconnections between the equipment and the interface locations.

Applicable Equipment:

Most equipment in the propulsion power plant can be considered applicable. Boilers, turbines, condensers, main feed pumps, heaters, coolers, modules, diesel engines, fuel pumps, lube oil pumps, strainers and filters.

Standard Format:

An example of a format which may be utilized for this equipment envelope standard follows. More than one format may be needed to satisfy the requirements of the many different types of equipment which fall into this category. The example depicts that for a Condenser Circulating Pump.

Example: First Page

Title: Description of equipment utilization.

Identification: Alpha-numerical standard identification with encoded type and size.

Application: General data with reference to the scope of this standard as to sizes, temperatures, pressures, and medium characteristics.

Next Page(s)

Performance Data Matrix: Chart showing capacity, pressure, temperature, and viscosity characteristics for each envelope size.

Pump Selection Charts: Capacity, Total Dynamic Head and Horsepower and model number of the vendor's available pumps for this service.

Next Page(s)

Pump Characteristic curves: for each model listed containing curves of Capacity versus Head, Horsepower, and Suction pressure

Next Page(s)

Outline drawings: With key dimensions of each model. Included are all interface dimensions, overall sizes, weights and bolting information for each module size.

Approvals: Includes regulatory agency approvals of module designs.

Equipment Suppliers: Includes the following lists with approvals noted if applicable.

1. Envelope manufacturers
2. Individual component manufacturers

Other Documents: Reference to other standards and specifications which are applicable.

Boilers, L.O. Purifier and main circulating pumps, as enveloped, will be economically analyzed in Sub-task 3.

On the following two pages, two examples of boiler envelopes are schematically explained. Figure 4-14 represents, in sketch form, an envelope for a boiler applicable to the 26,000 SHP steam plant and Figure 4-15 is the sketch of a boiler envelope suitable for the 40,000 SHP steam plant. Both envelopes scan *use* the products of any U.S. boiler . manufacturers without changing the size of the envelope and the interface locations.

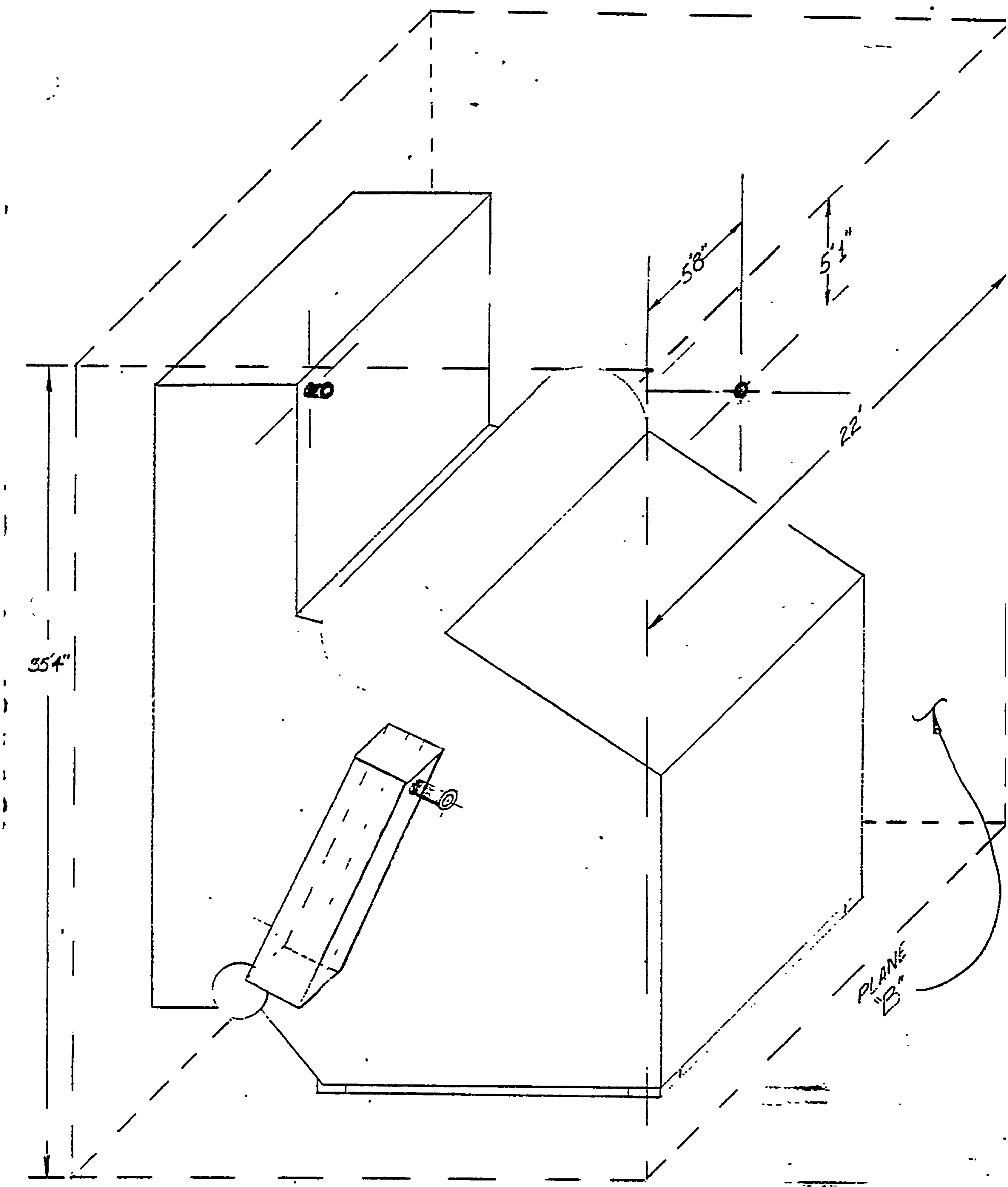


Figure 4-14 BOILER ENVELOPE

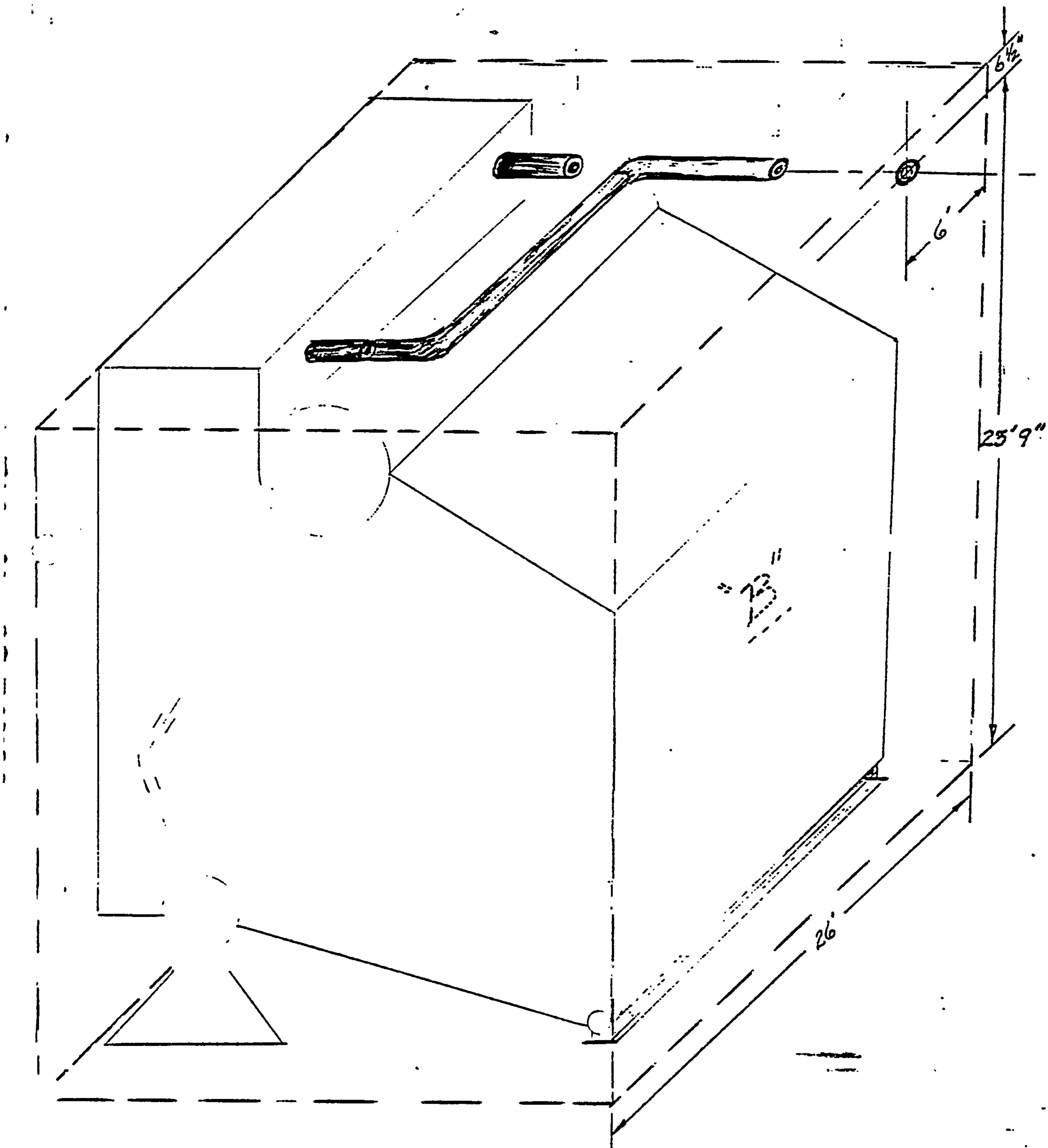


Figure 4-15 BOILER ENVELOPE

4.5.3.4 GROUP VI ndividual Equipment/Components

These standards are documents which contain the information in standard format which is required for shipyards to purchase vendor equipment required for propulsion machinery. These documents contain both the technical documentation and the legal documentation. Included are standard software items such as installation drawings, technical manuals, curves and calculations as appropriate.

Equipment subject to this type of standardization are: boilers, turbines, condensers, air ejectors, feed heaters, reduction gears, d.c. tanks, f.o. heaters, l.e. coolers, controls, feed pumps, circulating pumps, 1.O. pumps, f.o. pumps. It is anticipated that several of these will be evaluated for economic benefits and feasibility.

It should be noted that equipment manufacturers have voiced objection to standardization of individtial equipment as being too restrictive and interfering with design philosophy. Shipyard purchasing specialists, however, feel that these types of standards can save much schedule time lost due to non-availability of parts.

Standard Format:

The legal portion of these standards will contain standard statements of Warranty, Price Adjustments, Terms of Payments, Liability Limitations, Loss Risks, Shipping, Delays, Changes, Drawing Approval Terms, Cancellation, and Taxes.

One standard technical format applicable to a pump purchase is described as follows:

4.5.3.4.1

EXAMPLE: First Page

Title: Brief Description of item by service

Identification: Standard identification number

Applicable Documents: Reference to requirements such as other standards, Regulatory agency specifications and requirements, etc.

Quantity of Purchase

Intended Service

Next Page(s)

Drawing Requirements: Included are information drawings, approval drawings and schedule of delivery

Instruction & Maintenance Manuals:

Physical Description: In chart form

Performance Data: In chart form

Materials Data: List

Weights

Spares

Inspection Requirements: Includes at vendors' sites and at delivery point requirements

Outline Drawing: This is an envelope or limit type drawing with information required for interface and to limit the vendor.

Performance Curves: Includes capacity versus head, horsepower and suction

Special Design Considerations: Contains any special considerations with which vendor must comply. Includes physical and chemical properties of recommended materials, special handling, heat treating, amb~~ient~~ conditions, etc.

Test Requirements: Specifies tests which must be performed by the vendor such as hydrostatic pressure tests and load run tests.

4.5.4 Refinement and Modification of the Grouping of Standards

The foregoing selection and grouping of standards and standards parameters were developed as a result of the procedures followed in the conduct of this study. At the conclusion of this phase of the study, several knowledgeable representatives of the shipbuilding industry, together with representatives of the prime contractor of the Ship Producibility Program, Bath Iron Works, were canvassed for their reaction to the results.

Augmenting the results of the study, the follwing comments and actions are applicable:

4.5.4.1 Group I - Total Propulsion Plant Standards

It was determined that standardization of total propulsion plants should be directed twards a systems approach and that standards should be carried to a level of systems piping diagram for each horsepower range selected. This group of standards would also be utilized as top level standards to key the total plant to lower level standards. in this sense, the total plant (Group 1) Standard is a top-level reference document which can be utilized in defining and designing the total propulsion plant, and contains in a standard format the performance parameters and operating characteristics on which the design of major systems for the total plant is based.

This definition of the total plant is different form the one developed in 4.5.2.1 and 4.5.3.1, for a steam turbine propulsion plant, in that parameters such as the procurement specifications, engine room arrangements, arrangement drawings, piping drawings, and installation drawings can no longer be included in the "standard" docu=m~for the total plant. The standards parameters that will be contained in the "Total Plant Standard" will then be as shown on Table 4-3, ~~on page~~

For a more detailed description of the contents of Group 1 Standards, please refer *to* 5.3.2.1 and 5.3.3.1.

4.5.4.2 Group II "Systems/Equipment Modules" Standards

It was found and believed that the original conclusions as reported in 4.5.2.1 and 4.5.3.2 were valid and acceptable to the industry. However, views were expressed to the effect that the selection of modules should be done very carefully and an efficient arrangement to suit limited space availability must be achieved. *It was* further expressed that the module design would normally be a shipyard function; the shipyards would develop their own modules and tailor them to suit their needs for individual ship designs.

Nevertheless, a consensus was reached that given a Group I Standard, Group II Standards can be developed, and this would enable the shipyards to perform a genuine' "make-or-buy" analysis.

4.5.4.3 Group III "Equipment Envelope" Standards

The original conclusions of 4.5.2.1 and 4.5.3.3 were reviewed and discussed. The generally-adopted view was that this group of Standards would result in loss of space and that due to this fact, the need to use space efficiently will probably preclude extensive use of envelope standards. However, it was considered likely that smaller machinery components, for which there may be little space limitation, may prove to be suitable for writing envelope standards. It must be emphasized that the major advantage of this standard is that it effectively establishes equipment standards (similar to Group IV Hardware Standard) without encroaching upon the independence of equipment manufacturers.

4.5.4.4 Group IV."'Individual Component Standards,

The consensus opinion was reached to the effect that Group IV Standards, if they can be implemented, will provide the greatest dollar-saving potential.

The question of which type of standards should be written and to what degree of detail should they go was resolved as follows: It was noted that the equipment manufacturers have voiced objection to hardware standardization as being too restrictive and interfering with with design and competitive sales philosophy. It was also observed that the shipyard purchasing specialists have felt that this group of standards can save considerable schedule time and benefit consecutive orders, maintenance and operation.

It was concluded that in addition to the originpl concept of a general software standard for equipment (Procurement Standard) acceptable to the industry, an economic evaluation be performed for an equipment standard (Hardware Standard). Realizing that adoption of this type of standard would be resisted by equipment manufacturers, it was determined to examine the potential of these *two* standards along with another concept of standards which can be called a "data standard". In suntnary, it was decided to adopt a "step-by-step" approach to complete equipment standardization.

a. The first step should include a survey of the available equipment. The data made available by the Manufacturers for their products would be presented in a Standard format. The format would establish the extent of information to be supplied. The shipyard, or the design agent, can then *use* the information contained in the Standard format in incorporating the equipment or the component into the ship design.

The document containing this information was label led a "Data Standard" and defined as follows:

<u>DATA STANDARD</u>: A formal written document which includes all technical information at the vendor level of-detail in a standard format. This Standard would enable the shipyard to incorporate the subject component into the ship design but it would exc[redacted] sales

documentaion.

b. The second step in the Standardization efforts for the individual components would be the development of a procurement document. This document would include both technical and legal data and all information would be presented in a Standard format. The information contained in this Standard format can be utilized by the shipyard in incorporating the subject component into the ship design as well as purchasing the said ccxnponent. This document was labelled a "Procurement Standard" and defined as follows:

PROCUREMENT STANDARD: A formal written document, which constitutes an intermediate step of Standardization, where all of the performance and operating characteristics and some *of* the physical characteristics are standardized. Procurement documents covering both technical and legal data are prepared in Standard formats.

c. The *last* step of standardization efforts for the individual components is the complete Standardization of the equipment itself as a hardware item. The component manufactured to this standard by one vendor would be interchangeable with the *product of another* vendor manufactured to the same Standard. The shipyard and/or the design agent can use the information contained in this document at all levels of ship design to any degree of detail desired as far as installation and interface requirements are concerned. The document can also be used in purchasing the component since it contains legal and sales data as well. The label "Hardware Standard" was assigned to this document and it was defined as follows:

HARDWARE STANDARD: A formal written document, which constitutes the final step of standardization, where the component in question is completely standardized and as such becomes an "off-the-shelf" itern.

For a more detailed description of the contents of Group IV Standards, please refer to 5.6.1.4.

4.6 CONCLUS10NS & RECOMMENDATIONS

4.6.1 GENERAL

Results of the investigation and selection of standards indicates that implementation of a standards program for U.S. shipbuilding is technically sound, has the prospects of being acceptable to the industry and shows good potential for achieving appreciable *cost* savings in shipbuilding. The forecast indicated that the shipbuilding industry will be in a healthy state at least through 1985. It therefore follows that a standards program be implemented immediately to gain the advantage offered, since such a program requires time and multiple ships to share real cost benefits.

This portion of the study has evaluated the technical potential as well a preliminary economic potential of the standards and results indicate that the standards selected may lend themselves *to* significant economic advantages. However, careful evaluation and consideration should be given to the selection of standards to be implemented and the priorities assigned. Industry acceptance is imperative for successful implementation of the standards. Developing standards to which industry is indifferent or finds unacceptable would negate any cost benefits to be realized since the implementation for the standards depends on their acceptance. The developed standards should be flexible and show enough economics potential to provide the incentives for acceptance. It is recommended that standards which require enforcing not be written until later in the program.

4.6.2 STANDARDS CANDIDATES SELECTED FOR ECONOMIC ANALYSIS

The purpose of this study can best be served by choosing a representative number of standards candidates, within each group, for economic analysis such that a generalization can be made as to the cost benefits of the entire group. In addition, the cost benefits for a representative ship may also be analyzed.

The standards candidates selected for economic evaluation within each group are the following:

GROUP I: Total Package Level - Standard Propulsion Plants

1. 26,000 SHP Steam Turbine Plant
2. 14,000 SHP Medium Speed Diesel Plant

GROUP II: Equipment/Systems Modules

1. Fuel Oil Service Systems Module
2. Main Feed Pump Module
3. Diesel Accessory Rack Module

GROUP III: Equipment Envelopes

1. Boiler Envelope
2. L.O. Purifier
3. Main Circulating Pump

GROUP IV: Individual Equipment Components

1. Condensate Pump
2. Starting Air Compressors
3. Boilers

For each one of the Group IV Components, economic analyses will be made covering the three different types of standards, i.e., the data standard, the procurement standard, and the hardware standard.

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4.6.3 GAS TURBINE PROPULSION STANDARDS

Standards were selected for gas turbine propulsion plants in paragraph 4.5.2.3, based upon the analysis of criteria. However, Gas Turbine Plants have been essentially standardized at the total package level in that the available plant sizes are limited. That is, each manufacturer markets a particular size (horsepower) gas turbine by type of which there is no competitive design, so that selection of the supplier is based solely on the design horsepower and type of turbine (Aircraft Derivative or Heavy Duty Industrial type).

In addition, each gas turbine manufacturer *has* a direct influence on (and may supply) the selection of the supporting equipment such as intakes, exhaust systems, waste heat boilers, lubrication and fuel systems and fuel oil treatment plants. Thereore it is deemed premature to attempt an economic analysis measuring the gains due to these standards. However, there is a critical need to develop standards to suit the marine industry for the performance, design and purchase of gas turbine propulsion plants. When the standards program is implemented, it is recommended that gas turbine propulsion plant standards be included. Consideration should be given to the Navy standard gas turbine program.

4.6.4 AUTOMATION SYSTEMS

Automation systems generally fall into three major propulsion modes, steam, gas turbine and diesel, although each offers different complexities. BAsed upon the criteria in this analysis, automation *systems* standards did not warrant selection for further analysis. However, since this major system within the total propulsion systems and since presently emphasis is being placed on "one man" or "unmanned machinery spaces, there is a great need for standardization of automation requirements. Standards for controls would greatly alleviate the present problems coordinating the various component controls towards automated machinery space operation. The economic gain in this area is questionable, since existing *systems* could not be utilized. in order to assure flexibility for future improvements 4 basic conservation system must be developed.

Appendix B.3 contains a complete description of the automation *systems* and possibilities of standardizing automation parameters. The results of this study can be summarized as follows:

1. <u>Degree of Automation</u>

It is recommended that a design be developed for "one man" watch in the machiner spaces as a standard. However, this design should have options which permit "unattended" operation of the machinery.

2. <u>Location of Control Stations</u>

it is recorranended that the main control be at an enclosed, air conditioned operating station in the engine room and the secondary control be at the bridge.

3. <u>Owner Required and Optional Equipment</u>

Standard control console should be suitable for arrangement to accept interfaces to owner required or optional equipment.

4. <u>Developments In Automation Technology</u>

The rapid development in electronic and fluidic technology drastically limits the parameters which can be standardized.

5. <u>Levels of Standardization</u>

Standardization of control consoles should not be applied beyond the physical size and weight limitations and the locations of interface connections.

6. Operational Characteristics

Of the operational characteristics of the automation systems, the following are recommended for standardization:

a. Method of Control - can be selected from the possible variations of pneumatic, hydraulic, electro-mechanical or electronic control methods.

b. Overall limit on Control Power Consumption - By the inclusion of this parameter into a standard, it will be possible to standardize the power source and inter-connections.

All other parameters such as performance requirements, number of control functions, etc., will depend on the degree of automation and the characteristics of the controlled machinery.

Even though the above described parameters are recommended for standardization in connection with the automation systems, no attempt will be made in the present study to economically analzye the benefits of standardization since these depend largely on the degree of standardization applied to the total plant.

4.6.5 ELECTRIC PROPULSION

Electric motor propulsion is a viable propulsion plant option which may be coupled with any of the prime movers, gas turbine, steam or diesel generators.

Equipment utilized in electric propulsion plants, however, have already incorporated appreciable use of standards. It is therefore concluded that no further analysis be performed with reference to electric propulsion. For a detailed description of electric propulsion standards; refer to Appendix B.2.

4.6.6 INHERENT PROBLEM AREAS

4.6.6.1 GENERAL

The disparity of ships, ship types, shipyards, shipyard locations and advantages (economic, technical personnel and capacities) renders the development of national standards very difficult. Because of these variables which affect a propulsion plant's design and acceptance, the standards must be general in nature and flexible so individual competition and preference are not stifled.

A great deal of credit must be given to shipyards. During the course-of this study it was ascertained that the thriving shipyards have standardized to an extent allowable by and modeled to their intrinsic capabilities and the particular characteristics of the vessel being constructed. Therefore, resistance to national standards arise from two sources: the disparities mentioned above and individual shipyard's attempt to maintain their advantage in their uniqueness and in their methods of standardization.

Parameters such as material specifications, clearances, etc., which cause a manufacturer to redesign, would meet with a great deal of resistance. The volume of business which the marine industry represents to the vendors as compared to the volume of business which the conmnercial non-marine bus'iness represents to the vendors is an important factor *to* be considered in this feasibility study. Many of the manufacturers have . expressed interest in this study; however, its impact is directly proportional to the relative volume of business. Some manufacturers have mentioned that the marine business represents less than five percent of their entire gross revenue; therefore, an attempt to drive their individual standards in any direction away from the standards set by shoreside industry would meet with resistance. In light of this, except in unique cases, the standards which may be developed would conform to *the* manufacturer standards, thereby, conforming to the commercial industrial standards.

4.6.6.2 Problems with Standardizing Total Propulsion plants

After reviewing the selected standards parameters, it was considered feasible to standardize on total propulsion plants classified by shaft horsepower ranges. (See Sub-Section 4.5.3.i - GROUP - Total Propulsion Plants.) However, *in* discussion with various shipyards, it was noted that their history of series production of various ship sizes led to standardization in specific SHP'S increasing by increments of five thousand (5,000).

Another problem with standardizing total propulsion plants arises when an owner desires a ship of less SHP than the maximum of that range; in order *to give* an owner less than maximum, the . equipment stays the same (since they are standard), but they operate at less than capacity. This lends itself to a more conservative plant but at the expense of efficiency. This can be offset by the added advantage of containing reserve for a future power increase.

When an owner elects a standard plant which needs certain changes to it (like a boiler with greater steam generating capacity than normal because of special , extensive auxiliary steam demand), the heat balance, capacities, etc., are all disturbed, and the standard will have to be modified.

Should the total package prove to be a standard of great potential, the prospective owner can be shown the economic advantage of selecting the standard.

4.6.6.3 Problems With Standardizing Systems/Equipment Modules

It is interesting to note that some shipyards have designed and installed many of the same modules (however, non-standard) which were selected as standards candidates in this study. However, these same shipyards did indicate certain problems with trying to implement national standards in this area. To package together equipment or to modularize systems is a difficult task to perform. The lower the module must be placed in the engine room, the more difficult the design task, especially on tankers. The vessels are narrower in the lower portions of the ship and narrowest aft; on tankers, the engine rooms are located aft where the beam is narrow and the web framing is large. Because of framing interferences and the narrowness of the beam, one shipyard mentioned that they could package equipment but had to tailor its design to each ship, even within the same series run of vessels of the same size.

There are a number of important considerations to be made in the design of modules. *Among* those which deserve mention and were common to discussions held with various shipyards are interferences such as piping and framing interferences provisions for walkways and maintenance space, and the flow of piping. Proper attention to these and other items may obviate the failure of the standard. Interferences may cause the same problem mentioned above - the need for tailored designs. The provisioning of the proper maintenance and walkway space may seem an obvious consideration, but many modules have become costly maintenance items because of the lack of consideration in this area. Piping designers attempt to design the flow of piping, in the engine room, in a parallel direction. The need to turn a standardized module to fit a ship, possibly because of interferences, may disrupt this flow of piping and cause interface problems.

Some of the-candidates which have been found technically feasible are-large and heavy. If such a standards candidate proves feasible by this study, then those writing the standards must investigate whether or not the weight and size of these items are greater than shipyard lifting capabilities and/or shipping capabilities.

Whether a module is assembled at the shipyard or bought from a manufacturer is a decision to be made by the individual shipyards. However, there are certain problems with manufacturer assembly which should be discussed here. Some shipyards, due to their geographic location, must rely on rail shipping and usually prefer to construct modules at their facility because of the probable damage to equipment caused by "humping" of railroad cards. They can also use labor to assemble modules during employment lulls.

Another, more obvious problem concerning the manufact- urer-assembled module is the coordination problem. In this situation, there is likely to be at least one additional control point. In addition, quality control might be increasingly difficult; *as* it exists today, many shipyards are complaining about the quality of the equipment they receive from the manufacturer.

4.6.6.4 Problems with Standardizing Equipment Envelopes

The envelope concept was developed to provide a means of standardizing the locations of interfacing piping without constraining individual manufacturers. Therefore, it is important to locate the interface points, on the envelope, at such a location as to be fair to all manufacturers. The envelope concept facilitates piping--kstal lations since it locates piping interfaces regardless of individual equipment manufacturer variations in piping locations. However, before this concept can realize any cost benefits in this area, an engine room arrangement or piping drawings, in part, must be developed. The location of interface points alone is not enough; the location of at least two interfacing equipment items must also be known to ascertain the direction and flow of piping.

The same problem exists with envelopes as with modules when the equipment must be turned to fit the ship. The flow of piping and interfaces may be disturbed.

As discussed in 4.1.3.3 and 4.5.4.4, however, the use of envelope standards, due to required additional space, may belimited. For smaller items of machinery where the space limitations may be less severe, the envelope standards may be suitable since the greatest degree of interchangeability of manufacturers is possible with this type of. standard.

4.6.6.5 Problems with Standardizing Individual Equipment/Components

The standards for individual. equipment/components should only be written after a survey of available equipment has been made. Again the problem remains, unless the standards conform to individual manufacturer's presently marketed designs, the standards will be unacceptable.

Care should be taken when writing standards for individual equipment/components not to include such restricting or inflexible parameters that they would cause manufacturer redesign or "stifle" competition. One shipyard told of Navy efforts to standardize turbo-generators. They attempted this through inflexible specifications, and it was received so poorly by manufacturers that there was only one bidder on the next buy the rest refused to bid. It was the consensus of shipyards and vendors that such standards would meet with similar resistance.

The above mentioned fact *was* one of the reasons for adopting a step-by-step approach to developing Group IV standards. As discussed in 4.1.3.4 and 4.5.4.1, it was recommended that three different kinds of standards be considered for individual components:

a. Data Standards

b. Procurement Standards

c. Hardware Standards

Inherent problems related to the standardization efforts in connection with-each of the above types of standards would be more or less eliminated as compared to the problems discussed in the beginning paragraphs of this sub-section. In other words, by adopting this 'phasing-in" of the Group IV standards, it is believed that a common ground could be found within the industry whereby the formal standards could be universally accepted and implemented. A considerable potential for enconomic advantages is obtainable in such a case.

4.6.7 AREAS FOR DESIGN IMPROVEMENT AND RECURRING PROBLEMS

During the research phase of this task, certain problem areas were highlighted. These included problems which recurred throughout the investigation. The follwing is a discussion of those problems with possible solutions as applicable to the standards program.

a. The most significant problem consists of approvals required for U.S. ship building in U.S. shipyards. American Bureau of Shipping (ABS) and U.S. Coast Guard (USCG) approvals are required for various segments-of-the propulsion plant. USCG approvals (or disapprovals) cause the greates schedule delays and cost increases.

Usually equipment detail and installation drawings and on-site inspections are required during several time phases of the building. Delays in approvals and time lost during negotiations for the required changes are cannon in the industry.

It is feasible that, should equipment standards be . utilized, the standard equipment and/or installaticm qay receive USCG & ABS approval, resulting in elimination of costly and time consuming delays. An added advantage to this feature is that this prior approval would be an added incentive to ship builders' top utilization of the standards.

b. Another universal problem facing shipyards is the late delivery of equipment. This also causes delays in schedule and increased costs. Many sub-modules are manufactured with substitute equipment (spool pieces) for subsequent installation of the primary equipment later in the schedule. This increases the cost, generally requires a much higher skill level of labor than originally intended and makes the ship highly vulnerable to equipment installation errors.

The utilization of standards within the propulsion equipment field could reduce the late delivery" problem by making standard equipment equivalent to "shelf items". A prospective manufacturer could stock standard items with littie risk of obsolescence. It is also probable that the manufacturing scheduling of standard equipment could more accurately be forecast to *reflect* industry requirements.

c. Another problem which has recurred is the lack of timely detailed installation information regarding propulsion equipment. This includes catalogue information and installation and outline drawings. This problem includes re-orders of previously used equipment for which the manufacturers very" often make significant modifications.

This problem can be virtually eliminated by the proper use of standards. The standard program, however, must include maintenance of the standards.

d. A very costly problem which has repeatedly been stated is the damage during shipment and resulting liability. This is more prevalent in the West Coast shipyards, since most equipment is manufactured in the southern and eastern parts of the country. Re-alignment after shipment and many repairs are often required.

This problem could possibly be alleviated by the use of standard shipping and packaging methods as well as universal indicating methods.

e. Another problem which seems to be universal is the poor quality control which has resulted in much on-site repair and re-work to make equipment operate. This is also a very costly shipyard operation.

The utilization of standards could appreciably increase *the* quality of the delivered product because of increased familiarity with the manufacturing and inspection procedures.

f. Required design improvements which have been uncovered in this study include the following:

* Re-heat boiler, steam turbine cycle. This *system* has merit due to the very efficient fuel oil rate.
* Gas Turbines - higher efficiencies and low grade fuels.
* Combined cycle propulsion plants.

For detailed discussions of above design improvements, please refer to Appendix D, "Future Study .Recoirunendations".

SUB-TASK - 2 REPORT

LIST OF APPENDICES

STANDARD STEAM PROPULSION

APPENDIX B.1.1

PLANT DATA

15-17500 SHP

TONNAGE RANGE

APPLICATION	TANKER	25-35000 DWT

1. Main Boilers (2)
   - Description: 2 drum, single furnace, water-tube, forced draft, superheater, economizer, air heater, steam atomization of burners, automatically controlled.

Steam Conditions:	850 PSI at 950° F.
Air Inlet Temp:	280° F.
Evap. (Capacity):	60,000 #/HR-(each)
Efficiency:	88.5
Feed Water Temp:	285° F.
Specific Fuel:	.5. #/SHP/HR
Size:	12' x 16' x 25'
Weight:	40 tons (ea)

2. Main Turbine 1 Set
   - Description: Cross-compound, impulse, single flow, astern element in L.P. turbine

Output:	17500 SHP
Turbine RPM	H.P.-6500, L.P.-3700
Steam Conditions:	600 PSI at 900° F.
No. Extractions:	2
Size:	H.P. - 5' x 12' x 10', L.P. - 12' x 25' x 12'
Weight:	24 tons

3. Main Condenser (1)
   - Description: Horizontal, straight tube, single pass, surface type, dual function.

Surface:	17,000 Ft^2
Capacity:	110,000 #/HR
Vacuum:	28.5"
Cooling Water:	30,000 GPM
Tube Diameter & Thick:	3/4" x 18 BWG
Material - Sheet, Plate, Sep:	90-10 Cu-N. Alloy
Size:	24' x 8' x 12'
Weight:	47 Tons

4. Reduction Gear — 1 Set
Description: Double reduction, double helical, articulated, reversible with lube oil pumps attached

*Rating: 17500 SHP at 110 RPM
*"K" Factors: 1st - 140, 2nd - 110
Size: 6' x 18' x 15'
Weight: 48 Tons
*Note: May Vary by Ship Type

5. Main Lube Oil Pump — (2)
Description: Vertical, rotary, motor driven; sump type

Capacity: 500 GPM
Head: 50 PSI
RPM: 1750

6. Forced Draft Fans — (2)
Description: Horizontal, centrifugal, cross-connected, motor driven

Capacity: 30000 CFM
Static Pres: 9" hg

7. Main Feed Pumps — (2)
Description: Horizontal, centrifugal, single stage, steam turbine driven

Capacity: 450 GPM
Head: 700 PSI

8. Fuel Oil Service Pumps — (2)
Description: Horizontal, rotary, motor driven

Capacity: 30 GPM
Head: 350 PSI

9. Main Circulating Pumps		(2)
	Description:	Vertical, single stage, centrifugal, motor driven
	Capacity:	17,500 GPM
	Head:	25 Ft at 600 RPM
10. Main Condensate Pumps		(2)
	Description:	Vertical, 2-stage, centrifugal, motor driven
	Capacity:	300 GPM
	Head:	200 Ft at 1750 RPM
11. Fuel Oil Heaters		(3)
	Description:	Horizontal, steam, 2-Pass, U-Tube
	Capacity:	12,000 #/HR
	Inlet T.:	100° F.
	Outlet T.:	250° F
	Steam Pres:	150 Psl
12. Lube Oil Coolers		(2)
	Description:	Horizontal, single pass, straight-tube
	Surface:	1200 Ft^2
	Inlet T.:	140° F.
	Outlet T.:	120° F
	Sea Water Temp:	86° F
	Material:	10-10 Cu-N-Alloy
13. Feed Water Heater(s)		Drain cooler (l), and Gland Exhaust Condenser
	Description:	Horizontal, multi-pass, straight tube, closed,

14. Deaerating Feed Heater (1)

Description:	Vertical, direct contact, deaerating spray type
Capacity:	140,000 #/HR
Outlet T.:	2850 F.

STANDARD STEAM PROPULSION

APPENDIX B.1.2

PLANT DATA

28-32000 SHP

		TONNAGE RANGE
APPLICATION	TANKER	1oo-150000 DWT
	RO/RO	20000
	LASH	22-27000

1. Main Boilers	(2)
Description:	2 Drum, single furnace, water-wall, superheater internal desuperheater economizer, air heater and full automatic combustion control
Steam Conditions:	850 PSI at 950° F
Air Inlet Temp:	450° F
Evap. (Capacity):	115,000 #/HR
Efficiency:	88.5
Feed Water Temp:	415° F.
Specific Fuel:	.45 #/SHP/HR
Size:	15' X 22' X 25'
Weight:	56 Tons (ea)
2. Main Turbine	1 Set
Description:	Cross-compound, impulse, single flow, astern elements in L.P. turbine
output:	32,000 SHP
Turbine RPM	H.P. 4300, L.P. 3500
Steam Conditions:	850 PSI at 950° F.
No. Extractions:	2
Size:	H.P. - 6' x 15' x 10', L.P. - 10' X 26' X 12'
Weight:	32 Tons
3. Main Condenser	(1)
Description:	Horizontal, single pass. surface type
Surface:	26000 Ft^2
Capacity:	150,000 #/HR
Vacuum:	28.5" Hg
Cooling Water:	37500 GpM at 6.o FPS
Tube Diameter & Thick:	3/4" X 18 BWG
Material - Sheet, Plate, Sep:	10-10 CU-NI alloy
Size:	27' X 12' X 15'
Weight:	60 Tons

4. Reduction Gear	1 Set
Description:	Double reduction, double helical, articulated, reversible with attached L.O. pumps
*Rating:	32,000 SHP
*"K" Factors:	1st - 140, 2nd - 110
Size:	10' X 26' X 18'
Weight:	65 Tons
Note: May Vary by Ship Type	
5. Main Lube Oil Pump	(2)
Description:	Vertical, rotary, motor driven sump type
Capacity:	600 GPM
Head:	60 PSI
RPM:	1200
6. Forced Draft Fans	(2)
Description:	Horizontal, centrifugal, motor driven
Capacity:	50000 CFM
Static Pres:	25" Hg
7. Main Feed Pumps	(2)
Description:	Horizontal, multi-stage, centrifugal, steam turbine driven
Capacity:	600 GPH
Head:	1200 Psi
8. Fuel Oil Service Pumps	(2)
Description:	Horizontal, rotary, motor driven
Capacity:	60 GPM
Head:	350 PSI

9. Main Circulating Pumps (2)

Description: Vertical, single stage, centrifugal, 2-speed, motor driven

Capacity: 27,000 GPM (total)

Head: 25’ at 600 RPM

10. Main Condensate Pumps (2)

Description: Vertical, centrifugal, 2-stage, motor driven

Capacity: 400 GPM

Head: 250 '

11. Fuel Oil Heaters (2)

Description: Horizontal, extended surfaces, shell and finned tube.

Capacity: 22,000 #/HR

F.O. Inlet T.: 100°F.

F.O. Outlet T.: 2500F.

Steam Pres: 150 PSI

12. Lube Oil Coolers (2)

Description: Horizontal, multi-pass-straight tube

Surface: 1000 Ft^2

L.O.inlet T.: 140° F.

L.O.Outlet T.: 120° F.

Sea Water Temp: 85° F.

Material: 90-10 CU-Ni

13. Feed Water Heater(s) - drain cooler and Gland leak-off Condenser (1)

Description: Horizontal, single shell, surface type

Capacity: 210,000 #/HR

Outlet T.: 185° F. .

14. Deaerating Feed Heater	(1)
Description:	Vertical, direct contact spray type
Capacity:	250,000 #/HR
Outlet T.:	285° F.

STANDARD STEAM PROPULSION

APPENDIX B.I.3

PLANT DATA

36-40000 SHP

APPLICATION		TONNAGE RANGE
	TANKER	240 280000 DWT
	LNG	6 5 0 0 0
	RO/RO	30000

1. Main Boilers	(2)
Description:	2 Drum, single furnace, water-wall economizer. superheater, internal desuperheater, air heater, full automatic combustion control
Steam Conditions:	850 PSI at 950° F.
Air Inlet Temp:	280° F.
Evap. (Capacity):	135,000 #/HR
Efficiency:	[illegible]
Feed Water Temp:	285°F
Specific Fuel	.48 #/SHP/HR
Size:	15′ X 25′ X 30'
Weight:	68Tons (ea)
2. Main Turbine	1 Set
Description:	Cross-compound, impulse, single flow, astern element in L.P. turbine
output:	40000 SHP
Turbine RPM	H.P. - 5650, L.P. - 3400
Steam Conditions:	850 PSI at 950° F.
No. Extractions:	4
Size:	H.P. - 6′ X 15′ X 10′, L.P. - 12′ x 31′ x 14'
Weight:	38 Tons
3. Main Condenser	(1)
Description:	Horizontal, singIe-pass, surface type dual function
Surface:	30,000 Ft^2
Capacity:	175,000 #/HR
Vacuum:	28.5" Hg
Cooling Water:	40,000 GPM
Tube Diameter & Thick:	3/4″ X 18 BWG
Material - Sheet, Plate, Sep:	90-10 CU-Ni Alloy
Size:	35′ X 12′ X 18′
Weight:	65 Tons

4.Reduction Gear		1 Set
	Description:	Double reduction, double helical, articulated with attached L.O. pumps, reversible
	*Rating:	40,000 SHP
	*"K' Factors:	1st - 140, 2nd - 110
	Size:	12′ x 32′ x 14'
	Weight:	80 Tons
	*Note: May Vary by Ship Type	
5. Main Lube Oil Pump		(2)
	Description:	Vertical, rotary, motor driven sump type
	Capacity:	700 GPM
	Head:	60 PSI
	RPM:	1200 RPM
6. Forced Draft Fans		(2)
	Description:	Horizontal, centrifugal, motor driven
	Capacity:	60000 CFM
	Static Pres:	25″ Hg
7. Main Feed Pumps		(2)
	Description:	Horizontal, multi-stage, centrifugal, steam turbine driven
	Capacity:	875 GPM
	Head:	1200 PSI
8. Fuel Oil Service Pumps		(2)
	Description:	Horizontal, rotary, motor driven
	Capacity:	60 GPM
	Head:	350 PSI

9. Main Circulating Pumps	(2)
Description:	Vertical, single stage, centrifugal, motor driven
Capacity:	40000 GPM (Total)
Head:	25″
10. Main Condensate Pumps	(2)
Description:	Vertical, 2-stage, centrifugal, motor driven
Capacity:	475 GPM
Head:	250 Ft
11. Fuel Oil Heaters	(3)
Description:	Horizontal, multi- pass,steam, straight, extended surface type
Capacity:	15000 #/HR
Inlet T.:	100° F.
Outlet T.:	250° F
Steam Pres:	150 PSI
12. Lube Oil Coolers	(2)
Description:	Horizontal, multi-pass, straight-tube
Surface:	1200 Ft2
L.O. Inlet T.:	140° F.
L.O. Outlet T.:	120° F.
Sea Water Temp:	850 F.
Material: .	90-10 CU-Ni
13. Feed Water Heater(s)	(3)
Description:	Horizontal, steam, single pass, surface with drain cooler
Capacity:	250,000 #/HR
Outlet T.:	280°F

14. Deaerating Feed Heater (1)

Description:	Vertical. direct contact, deaerating spray type
Capacity:	200,000 #/HR
Outlet T.:	280° F.

STANDARD STEAM PROPULSION

APPENDIX B.1.4

PLANT DATA

43-45,000 SHP

TONNAGE RANGE
375-450,000 DWT

T A N K E R

APPLICATION

1. Main Boilers		(2)
	Description:	2-drum, water wall, economizer, superheater, internal desuperheater air heater, full automatic combustion control.
	Steam Conditions:	850 PSI at 950° F.
	Air Inlet Temp:	280° F.
	Evap. (Capacity):	160,000 #/HR
	Efficiency:	88.5
	Feed Water Temp:	280°F
	Specific Fuel:	.48 #/SHP/HR
	Size:	20' x 28' x 30'
	Weight:	80 Tons (ea)
2. Main Turbine		1 Set
	Description:	Cross-compound, impulse, single flow, astern . element in L.P. turbine
	Output:	45000 SHP
	Turbine RPM	H.P. - 4360, L.P. - 3410
	Steam Conditions:	850 PSI, 950° F.
	No. Extractions:	4
	Size:	H.P. - 6' x 15' x 10', L.P. - 14' x 32' x 15'
	Weight:	47 Tons
3. Main Condenser		(1)
	Description:	Horizontal, single pass, surface dual function
	Surface:	35,000 Ft^2
	Capacity:	225,000 #/HR
	Vacuum:	28.5″ Hg
	Cooling Water:	47,500 GPM
	Tube Diameter & Thick:	3/4″ X 18 BWG
	Material - Sheet, Plate, Sep:	90-10 CU-Ni Alloy
	Size:	36′ X 14′ x 20'
	Weight:	80 Tons

4. Reduction Gear		1 Set
	Description:	Double reduction, double helical articulated, reversible with attached L.O. Pumps
	*Rating:	45000 SHP
	*"R' Factors:	1st - 140, 2nd - 110
	Size:	12' x 32' x 16'
	Weight:	110 Tons

*Note: May Vary by Ship Type

5. Main Lube Oil Pump		(2)
	Description:	Vertical, rotary, motor driven sump type .
	Capacity:	700 GPM
	Head:	60 PSI
	RPM:	1200
6. Forced Draft Fans		(2)
	Description:	Horizontal, centrifugal, motor driven
	Capacity:	70,000 CFM
	Static Pres:	30" Hg
7. Main Feed Pumps		(2)
	Description:	Horizontal, multi-stage, centrifugal, steam turbine driven
	Capacity:	950 GPM
	Head:	1200 PSI
8. Fuel Oil Service Pumps		(2)
	Description:	Horizontal, rotary, motor driven
	Capacity:	60 GPM
	Head:	350 PSI

9. Main Circulating Pumps (2)

Description:	Vertical, single stage, centrifugal motor driven
Capacity:	50000 GPM (Total)
Head:	25 Ft

10. Main Condensate Pumps (2)

Description:	Vertical, centrifugal, 2-stage, motor driven
Capacity:	600 GPM
Head:	250 Ft

11. Fuel Oil Heaters (3)

Description:	Horizontal, multi-pass, straight tube, steam
Capacity:	15000 #/HR
F.O. Inlet T.:	100° F.
F.O. Outlet T.:	250° F.
Steam Pres:	150 PSI

12. Lube Oil Coolers (2)

Description:	Horizontal, single-pass, straight-tube
Surface:	1200 Ft^2
L.O. Inlet T.:	140° F.
L.O. Outlet T.:	120° F.
Sea Water Temp:	85° F.
Material:	90-10 CU-Ni

13. Feed Water Heater(s), Gland Exhaust Condenser and Drain Cooler (1)

Description:	Horizontal, single-pass, steam, straight tube
Capacity:	310,000 #/HR (Total)
Outlet T.:	

14. Deaerating Feed Heater (1)

Description:	Vertical, spray type, direct contact deaerating
Capacity:	310,000 #/HR
Outlet T.:	285° F.

STANDARD STEAM PROPULSION

APPENDIX B.1.5 PLANT DATA

50,000+ SHP

TANKER

TONNAGE RANGE
450,000 DWT

APPLICATION

1. Main Boilers		(2)
	Description:	2-Drum, water-wail-superheater economizer, internal control desuperheater, air heater, full automatic combustion control
	Steam Conditions:	850.PSI at 950° F
	Air Inlet Temp:	3000 F.
	Evap. (Capacity):	180,000 #/HR
	Efficiency:	88.5
	Feed Water Temp:	415° F.
	Specific Fuel:	.48 #'/SHP/HR
	Size:	22' X 28' X 30'
	Weight:	110 Ton (ea)
2. Main Turbine		1 Set
	Description:	Cross-compound, impulse, single or double flow, astern element in L.P. Turbine
	output:	50000+ SHP
	Turbine RPM	H.P. - 4500, L.P. - 3600
	Steam Conditions:	850 PSI at 950° F.
	No. Extractions:	4
	Size:	H.P. - 8' x 15' x 10', L.P. - 15' x 32' x 15'
	Weight:	65+ Tons
3. Main Condenser		(1)
	Description:	Horizontal, deaerating, surface, multi-pass, dual function
	Surface:	45000 Ft^2
	Capacity:	275000+ #/HR
	Vacuum:	28.5" Hg
	Cooling Water:	50,000+ GPM
	Tube Diameter & Thick:	3/4" X 18 BWG
	Material - Sheet, Plate, Sep:	90-10 CU-Ni
	Size:	40' X 16' X 18'
	Weight:	100 Tons

4. Reduction Gear — 1 Set

Description: Double Reduction, Double helical, locked train, reversible with L.O. pumps attached

*Rating: 50,000+ SHP

*"F' Factors: 1st - 140. 2nd - 110

Size: 20' X 25'x22'

Weight: 140+ Tons

*Note: May Vary by Ship Type

5. Main Lube Oil Pump — (2)

Description: Vertical, rotary, motor driven sump type

Capacity: 700 GPM

Head: 60 PSI

RPM : 1200

6. Forced Draft Fans — (2)

Description: Horizontal, centrifugal, motor driven

Capacity: 75000+ CFM

Static Pres: 30" Hg

7. Main Feed Pumps — (2)

Description: Horizontal, multi-stage, centrifugal, steam turbine driven

Capacity: 1000 GPM

Head: 1200 PSI

8. Fuel Oil Service Pumps — (2)

Description: Horizontal, rotary, motor driven

Capacity: 60 GPM

Head: 350 PSI

9. Main Circulating Pumps (2)

Description: Vertical , single stage, centrifugal motor driven

Capacity: 50 ,000+ (Total)
Head: 30 Ft

10. Main Condensate Pumps (2)

Description: Vertical, centrifugal, 2-stage motor driven

Capacity: 600 GPM
Head: 250 Ft

11. Fuel Oil Heaters (3)

Description: Hori zontal, steam, multi-pass strai ght tube.

Capacity: 15000 #/HR
F.O. Inlet T.: 100° F.
F.O. Outlet T.: 2500 F
Steam Pres: 150 Psl

12. Lube Oil Coolers (2)

Description: Horizontal, single-pass, straight-tube

Surface: 1400 Ft^2
L.O. Inlet T.: 140° F.
L.O. Outlet T.: 120° F.
Sea Water Temp: 85° F.
Material: 90-10 CU-Ni

13. Feed Water Heater(s), Gland exhaust condenser and drain cooler (1)

Description: Horizontal, single-pass, steam, straight tube

Capacity: 350.000 #/HR
Outlet T.: 285° F.

APPENDIX B.1.6

STANDARD DIESEL PROPULS10N PLANT DATA

8-10000 SHP

Tonnage Range

APPLICATION BULK/GEN . CARGO 25000 DWT

1. Main Engines (1)

Description:	4-cycle, v-16, marine, turbo-charged, pneumatically coupled.
Rating:	10000 BHP at 400 RPM
Bore/Stroke:	17" x 21"
BMEP :	195 psi
Size:	23' X 14' X 16'
Weight:	115 Tons

2. Controls

Type:	Automatic centralized control; remote engine and propeller control; automatic instrument monitoring and recording
Classification:	Manned, ACC/ABS Certification"
Equipment:	Data, alarm loggers, automatic and manual control modes, digital display and constant readout gages
Location:	Main control console - Engine Room

3. Compressed Air System

Compressor Description:	Two, 2-stage, 2 cyl. motor driven, automatic
Capacity:	100 CFM
Pressure:	600 PSI
RPM:	875

4. Exhaust Gas Boilers (1)

Description:	Horizontal, single gas pass, water tube, waste heat recovery
Capacity:	2500 #/HR
Pressure:	150 PSI
Temp. :	250° F. .

5. 5. M.E. Fresh Water Coolers (2)

Description:	Horizontal, straight tube, double pass. raw water
Surface:	350 Ft^2
Outlet:	200° F.

6. M.E. Lube Oil Coolers (2)

Description: 'Horizontal, 2-pass. , raw water, straight tube
Surface: 500 Ft^2
Outlet: 200° F.

7. Fuel Oil Heaters (1)

Description: Horizontal, 2-pass., straight tube, steam
Surface: 125 Ft 2
Temp. : 200° F.

8. Fuel Oil PUrifier (1)

Description: Centrifugal , automatic, motor driven
Capacity: 450 GPH
Heater: 18 KW

9. Lube Oil Purifier (1)

Description: Centrifugal, automatic, motor driven
Capacity: 350 GPH
Heater: 25 KW

10. Fuel Oil Booster Pumps (1)

Description: Vertical, centrifugal , motor driven
Capacity: 40 GPM
Head: 60 PSI

11. M.E. Lube Oil Pumps (2)

Description: Vertical, centrifugal , motor sump type
Capacity: 600 GPM
Head: 75 PSI

12. M.E. Cooling Water Pump (2)

Description: Horizontal, centrifugal, motor driven
Capacity: 1000 GPM
Head: 60 PSI

13. Main Salt Water Pumps (2)

Description: Horizontal, centrifugal, motor driven
Capacity: 1500 GPM
Head: 75'

14. <u>Reduction Gear</u> (1)

Description:	Single reduction, double helical, attached -R.G. L.O. Pumps, non-reversible, twin pinion, clutch connected
Rating:	10000 SHP at 130 RPM
Gear/Ratio: “	, 3.5/1
NOTE :	May be designed with reversing capabilities. in lieu of a CP Propeller.

APPENDIX B-2

ELECTRIC PROPULSION

1. General

Historically, electric drive systems have been in use in the United States since 1912 when the Collier USS Jupiter was converted into the first aircraft carrier and renamed the USS Langly. Subsequently, electric drive systems were increasingly used until the shortage of reduction gears during World War Ii spotlighted electric drive systems as a suitable alternate for the reduction gears on board T-2 tankers. At this point, the number of electric drive systems dramatically increased, and the success of the T-2 tanker design is directly attributed to its electric drive system.

After World War 11, the availability of reduction gears with their associated efficient operation and lower cost, pushed electric drive systems into the background. However, in recent years due to the development of solid state controls, computer aided equipment designs and the development of better insulation, shipboard electrical equipment has become more efficient, smaller in volume and weight, and more cost effective than previous equipment.

In recent years, the off-shore oil industry has developed drilling ships and platforms with electric drive systems. This was due to the fact that the on-station drilling equipment requires a very large electrical power plant which would be idle during transit if another use could not be found. Of course, the obvious answer was a single power plant in a multiple use application, namely to provide power for drilling operation on-station and power for the propulsion system in the transit node. Today, nearly all oil drilling ships and semi-submersible platforms utilize this type of power system and to the oil industry this concept is not only reliable but also cost effective.

The biggest advantage of electric drive systems is in the area of equipment arrangement. The propulsion motor(s) can be located remotely near the shaft penetration of the ship, thereby eliminating the need for long shafts, shaft alleys and the associated clear space required for safe operation. The prime movers and generators, and switchgear can be judiciously located in an arrangement which would efficiently utilize ship space due to the elimination of all mechanical connections between the drive and its power source. This approach wiIl eliminate the engine room concept as we know it today and in general, more closely resemble the Chevron tankers under construction in Portland, Oregon. In this manner, a more compact engine room with increased space for cargo or a smaller ship with the same cargo capacity can be constructed. However, it must be pointed out that the extent this concept can be implemented would be a function of the electrical system in conjunction with its prime mover.

Propulsion systems such as multiple DC motors driving a single shaft through a common gear will not be investigated due to their unique application to the oil industry. In addition, super-conducting electric drive systems will not be investigated due to the research and developnmt still required to achieve status as a viable system for the vital function of propulsion. For this program, we will investigate the standard electric drive systems as to their application and cost effectiveness. Accordingly, all systems and equipment selected will be within the state of the art with sufficient experience that if chosen, they could be readily identified for standardization.

2. <u>Electric Propulsion Systems</u>

A recent article in Marine Engineering Log described marine electrical propulsion plants as, being in two broad categories, D.C. and A.C. systems. They stated that D.C. systems find application primarily in the low moderate power range (1000 to 6000 hp per shaft) while A.C. systems are more generally found in the medium- to high-power ranges (to 60,000 hp per shaft). in order to properly appreciate the workings of each system for comparison and application, a functional description of each system, including a hybrid system, follows:

a. Direct Current Systems

These systems usually consist of a shunt-wound D-C motor directly connected to the propeller shaft, fed from a multiplicity of generators, connected either in a series or parallel arrangement. A series-loop connection is more normally found, as it has rather basic advantages in ship propulsion. The generators can be lower voltage machines, and a series connection prevents over-loading of one machine if the other is shut down. If, however, there are more than three generators in the loop feeding one motor, then a paralled connection might be advantageous.

Basic control of a D-C propulsion drive is accomplished by varying the generator voltage by means of voltage control on the field. The process is smooth and simple, and lends itself readily to remote control. Pilot-house control of D-C propulsion drive systems, giving continuous speed control from full ahead to full astern, goes back 40 years. This ease of control also facilitates the use of multiple control stations.

A unique feature of the D-C electric drive is its ability to adapt itself to a range of propeller power versus speed characteristics. This characteristic changes somewhat with hull condition and vessel loading, but these changes are not very large and can be accepted without major effects on the propelling machinery. However, when a vessel is stuck in ice, or has a heavy tcw, the propeller will exhibit a very different torque-speed characteristic. Herein is the reason D-C motors have been used recently for ice-breaker propulsion systems. This type of system will match the speed-torque characteristic of any prime mover to the variable propeller characteristic, so full engine power can be utilized throughout the range of stalled to free-running ships in both forward and reverse directions.

This adaptability is obtained by selecting the propeller motor so that it can develop full power at the stalled ship propeller speed, and then weakening its field strength to match any other full power propeller speed up to that of the free-running condition. In effect, the system provides a variable speed ratio between the prime movers and the propeller. It also can-operate at relatively high overcurrents for the short time needed to reverse or accelerate the propeller. This rapid propeller.response can be achieved without overloading the-driving engine(s), since the system voltage is low and the KW input below that of rated.

b. Alternating Current Systems

These systems usually consist of a directly connected, high-speed generator(s) furnishing power to a single, low-speed synchronous motor on the propeller. With synchronous machines, there is a fixed ratio of speed between the generator and the propeller motor. The ratio is governed by the ratio of the number of poles on the motor to the number of poles on the generator. As an example, a two-pole generator operating at 3600 rpm could supply power to a 60-pole synchronous motor, causing it to turn at 1/30 of the generator's speed, or 120 rpm. As in the A.C synchronous system, both generator and motor are locked-in with frequency. it is useful to think of such generators and motors. as being electrically "geared" together.

A.C. drive equipment when compared with its D.C. counterpart have many advantages in weight, size, cost, maintenance and simplicity. This. kind of propulsion is-particularly adaptable to ships requiring high power since both A.C. generators and motors readily can be built for powers of 50,000 hp and more. A.C. drives are most suitable for ships that spend a high proportion of their operating time at or near full rather than at severely reduced power or in frequent maneuvering service.

Voltage levels found on A-C propulsion systems will range from about 2300 to 15,000 volts, with the largest power units being associated with the higher voltages. Voltages are selected on the basis of motor and generator design considerations and on the basis of available switching devices.

The induction motor was operated on early installations because its torque performance afforded the conservatism. necessary on an application where little was known about the actual torque requirements of a propeller under maneuvering conditions. After experience was gained with the induction motor drives, the more desirable synchronous motor was applied with success. By providing the synchronous rotor field with a special pole face or “amortisseur" winding, it could be operated as a squirrel-cage induction rotor during maneuvering, and then switched to synchronous mode as it came up to the proper synchronous speed with the generator(s).

Among the advantages of the synchronous motor are a high efficiency (98 percent) and the ability to operate at 100 percent power factor. There is also the flexibility of installation found in other electric drives, as well as the ease of reversing. Although A.C. drive equipment can be built in much larger ratings than is possible with D-C drives, it doesn’t have quite the smooth, stepless control that latter enjoys.

In the A-C synchronous ystem, speed control of the propulsion motor is obtained by varying the speed of the prime mover and consequently the frequency of the generator and propulsion motor. Turbine speed can be varied over a range from approximately 20 percent to 100 percent speed. However, below this speed, the excitation voltage is cut off and the motor operates as a standard squirrel cage induction motor.

As in the D-C system, there has to be an excitation subsystem. But this one must provide the motor and generator-field power requirements for 1.0 power factor synchronous operation and also must be able to over-excite the propulsion generator during starting and reversing of the propulsion motor. Below 20 percent speed, the motor power factor will be very low and its current demands high, requiring this over-excitation of the generator windings. These conditions are particularly severe when the motor is reversed from a full ahead operating condition, because the ship continues to move through the water at considerable speed, and the water flowing through the propeller area causes it to resist the efforts of the motor to stop and reverse it.

With an A-C drive, it is necessary to have a separate source of excitation power. It is not practical to employ shaft-drive exciters because of the wide speed range of the turbine-generating sets, and the fact that the exciter must provide considerably more excitation during the lower speeds of maneuvering than at the higher speeds for transit. This cannot be done at the minimum generator speed, thus excitation is commonly supplied from separate H-G sets or static exciters operating from the ship’s service power system.

Under steady running conditions, sufficient excitation must be maintained on the main generator so that the motor does not pull out of step because of torque variations on the propeller. A voltage regulator acts automatically to provide increased excitation, when torque variations from turning, high seas or other aberations warrant it.

c. Rectified A.C. Drive Systems

The recently developed silicon rectified (thyristor) makes possible the use of high-speed A-C generator sets to provide power to D-C propulsion motors. This hybrid retains the favorable speed-torque and control characteristics of the conventional D-C system and permits large, high-speed prime movers. High propulsion shaft horsepower can be obtained by double or triple-armature D-C motors. About 15,000 hp per motors armature is the limit.

This system is comprised of one or more high-speed A-C generator sets, silicon rectifiers, and a D-C motor usually directly connected to the shaft. Additional flexibility over that of other systems is possible, because a transformer is normally inserted between the generator and rectifier, thus allowing the designer to choose independently the optimum voltages for the generator and for the motor.

Except for the insertion of the transformers and rectification units between the A-C generators and the D-C motors, the design of the rectified ship propulsion system follows the general design standards previously described. There may be a small sacrifice in efficiency with such a system, but it allows for the first time the maneuvering flexibility of the D-C system in the high powers normally associated with the A-C system.

3. Electric Drive Equipment Analysis for Standardization

A careful review of the three basic electric drive systems previously described indicates that each system consists of three major subsystems, namely electric power generation, transmission and drive motor. In the case of the hybrid system, the additional elements of transformers and rectifiers are inserted into the power transmission subsystem which in effect only changes the voltage and current form.

The generator subsystem consists of the generator frame, insulation, copper conductors for rotor, stator and field windings, copper bus bars, bearings, brushes and brush holders, cable connection box, ventilation systems, etc., all of which have undergone many iterations of standardization. The National Electrical Manufacturers Association (NEMA) has previously standardized all generator frame sizes based upon horsepower and speed in their standards publication, “Motors and Generators, MG-1”. Today, major manufacturers of generators have computerized, and.in effect, standardized all generator designs to such a degree. that special requirements for changes from the norm in electrical characteristics will be contained in a standard generator enclosure. Accordingly, the generator subsystem is not a candidate for standardization.

The electric power transmission subsystem consists of cables for the pure AC and DC drive systems and for the hybrid system, consists of cables, transformers and rectifiers. Cable current carrying capacities based upon conductors’ cross-sectional area, insulation type and ambient temperature have been previously standardized by the Institute of Electrical and Electronic Engineers in their standard for marine electrical equipment, “IEEE Std. No. 45” and by the U.S. Navy in their publication “Cable Comparison Guide, Navships 250-660-23”. Accordingly, marine electric cables are considered to be sufficiently standardized as to offer no potential savings by further investigation.

Transformers are basically constructed of an iron core with primary and secondary windings which consist of copper conductors with appropriate number of. turns wrapped around the iron core. At a cost of $10-15 per K and the simplicity in the design of the transformer, it has been concluded that it offers no potential for further standardization or cost savings.

Rectifiers for hybrid electrical drive systems transform a multi-phase AC voltage" into a two-wire DC voltage at an appropriate power rating. Presently, the oil industry's experience is centered around SCR type rectifiers in the 1000 KW range with some applications in the 1500 KW range. Other. applications for propulsion drives at larger power ratings have just recently come into prominence. Such ships as the Washington State Ferry and the new U.S. Coast Guard.Ice Breaker are utilizing rectifiers with a. capacity of 1900 to 2500 KW. Over-all, the lack of experience with large capacity rectifiers would make an investigation into their potential for standardization premature at this time.

The motor subsystem has undergone the same development as the generator subsystem and is presently standardized to a degree that it cannot be considered a candidate for-further standardization.

4. summary

The electric drive systems that are used for propulsion power on ships of the U.S. Maritime fleet, have been previously standardized by equipment manufacturers and by requirements of the regulatory bodies. It appears that further investigations will not produce any benefits to the ship owner, ship builder or equipment manufacturer.

In addition, the cost of an electric drive system is much greater than one of the standard direct drive systems. The system operational efficiency is less than alternative systems due to the higher transmission losses. Unless the propulsion generating plant can be utilized for multiple applications, such as for roll-on/roll-off ships or ships with self-contained handling equipment, the electric drive system will not be a viable candidate for propulsion drive on most of the ships involved in this program.

The major advantage for an electric drive system is in the flexible arrangement between the power generation units and the *drive* motor(s). Since there is no mechanical linkage, new equipment arrangements are feasible where space can be more efficiently utilized and thus provide an increase in cargo stowage capacity. it is in this area, and not standardization *of* equipment, where the major benefits to the maritime industry can accrue.

APPENDIX 8.3

Technical Feasibility of Standardizing Propulsion Automation Systems

1. Background

Despite the common practice of redesigning propulsion automation systems for each ship design, a degree of similarity exists among all control systems for the same type of propulsion plant. This similarity is probably due to the high degree of commonality among various propulsion plant designs and to the similarity between requirements of the regulatory bodies that are usually invoked for each ship design. All such requirements are intended to provide only basic control and safety features, and often show a high degree of correlation.

The similarity between propulsion plant designs has been estimated to be as high as 80 - 90% by a recent Maritime Administration study on control console standardization (Maritime Administrateion Guide for a Standardized Engine Room Propulsion Control Console) (Reference 4-1). The degree of similarity in control systems, however, does not approach this high level. In studying the technical feasibility of developing standard control system designs, the parameters that cause greater diversity in control systems must be identified.

2. Parameters Affecting Standardization

Currently, diversity among control systems is caused in part by variations in power plant design and choice of plant vendor. A basic postulate in this study of control system standardization is that a . standard propulsion plant has been designed, and that these differences no longer exist. With these factors set aside, other parameters that affect control system design can be identified. It is these parameters that will define the feasibility of control system standardization and, if feasible, the extent to which standardization can be applied. They are as follows:

a. Degree of Automation

There are three generally recognized degrees of automations denoted by the minimum number of engineering watchstanders required to be present to monitor and control the propulsion plant, and designated as:

(1) Two man watch

(2) One man watch

(3) Unattended machinery space.

Naturally, as the number of watchstanders is reduced, the complexity of the control system must be increased to maintain a satisfactory level of control and supervision over the propulsion plant. This means an increased number of control , monitoring and alarm functions, and affects the controlled machinery, the engine room control console, and the bridge control console.

b. Location of Control Stations

The location of a main control console, with respect *to* the propulsion plant and the engine room, also affects the design of the propulsion control system and the extent of control, monitoring and alarm functions that are required. Common locations for a control station are:

(1) Within the engine room, unenclosed, usually near the boiler front for a steam driven ship.

(2) Within an enclosed operating room, located in the engine room, usually air conditioned and provided with windows that provide a direct view of the propulsion plant.

(3) Remote from the engine room, requiring closed circuit TV and sound monitoring for supervision of the propulsion plant.

As the main control station is moved to *more* remote locations with respect to the propulsion plant, the complexity of the control and monitoring system usually increases. The control station location also affects console components in that systems required to operate within an engine room environment, without the benefit of air conditioning, must be designed *to* tolerate higher temperature, humidity and exposure to oil vapor and other contaminants that may be present.

The bridge is almost universally chosen as the location for the secondary propulsion control station. Some propulsion controls may also be provided at other secondary control stations such as at bridge wings.

c. Differences Among Rules and Regulations

A comparison of the detailed requirements of various regulatory bodies applicable to ships built in the United States has previously been documented in a Maritime Administration study on ship design improvement (A Report to the U. S. Department of Commerce, Maritime Administration for the Ship Design Improvement Project) (Reference 4-2). The differences that exist between these regulatory bodies are not considered to be an important cause of diversity among control system designs since the same group of regulatory bodies are normally invoked for most ships built in the United States. These rules are therefore more responsible for the similarities in control system design, than differences, as all manufacturers of control systems are required to produce designs capable of meeting the same combination of requirements.

As designs capable of satisfying all applicable regulatory bodies do exist, and as differences between regulatory bodies are not an important cause of diversity in control system design, it will be assumed that this parameter will not significantly affect design of a standard control system.

d. <u>Owner Required and Optional Equipment</u>

This classification of equipment is intended to cover all items not required by regulatory bodies and not essential for control and safety. Such additional equipment may include:

(1) Data loggers and bell loggers

(2) Additional control, monitoring and alarm points

(3) Vibration and noise analysis equipment

(4) Maintenance and condition monitoring equipment

(5) Additional control stations (such as at bridge wings).

The addition of this type of equipment may sometimes, but not always, affect the propulsion control console design. Some equipment will only require additional interface points (terminal strips or external junction boxes), others may only require a revision to installation arrangements. While a standard console design can be expected to accommodate some additional equipment, demands for other equipment may require development of alternate standard designs or the use of a non-standard design.

e. <u>Developments in Control System Technology</u>

The rapid rate of technology progress makes obsolescence a constant threat to the feasibility of any standard design. Currently, this threat represents a greater danger to a standard control system design than to a standard propulsion plant design. The rapid rate of development in the electronic, fluidic and control technology fields limits the useful life of today's control systems to a shorter time span than can be anticipated for the propulsion plant it will control.

3. Candidates for Standardization

in a previous study (Reference 4-1) the Maritime Administration *set* guidelines for the design and development of a standardized engine room console. This study resolved some of the differences among control system design by postulating a basic control console capable of accepting optional features that may be added without changing the basic console arrangement. The basic console is arranged for a one-man watch and located within the engine room at the boiler front. The study also sets various locations and operating requirements for some propulsion auxiliaries.

In cases where standardization of a parameter leads to a control system that is less desirable because of its inflexible arrangement, the approach to standard design can follow the approach taken in the previous Maritime Administration study. The Mritime Administration guidelines, for example, permit adaptation of their basic console to an unattended machinery space operation if one-man watch operation is unacceptable *to* a potential owner. The Maritime Administration study recognizes inflexibility of design as one of the pitfalls of standardization. In selecting candidates for standardization, this study must also define possible adverse effects, and means by which these effects might be minimized, in order to define the technical feasibility of standardization.

a. Degrees of Automation

Choosing a standard degree of automation will affect the entire propulsion plant, not just the control system. The number of monitored and alarmed points, and the extent of remote and automatic controls change with different degrees of automation. Each point must be reflected on the controlled machinery itself as a control sensor or activator. Thus, the standardization of propulsion machinery is closely related to standardization of the degree of automation.

It is possible to develop standard control system designs, despite the existing variety of degrees of automation, by using one of the following procedures:

(1) Develop a single standard control system for one degree of automation.

(2) Develop more than *one* standard control system design, each offering a different degree of automation.

(3) Develop one or more standard designs, each with options intended to accommodate more than one degree of automation.

The Maritime Administration guide for standardization of propulsion control consoles (Reference 4-1) uses the last procedure, recommending a design for a one-man watch with options that would permit unattended operation. The fact that a single console can accommodate both one-man and unattended operation is possible because most control features are common to at least *two* degrees of automation. Thus, only two standard designs for most machine units would be required to accommodate all three levels of automation. Where differences in requirements for control features for any machine unit require only simple hardware changes, these changes can be offered as options to a single basic component design.

As current trends appear to be approaching higher levels of automation, initial standards should concentrate on developing designs for unattended operation. Alternate designs for lower levels of automation can then be developed if justified by demand.

b. Location of Control Stations

Although the Maritime Administration guide for propulsion console standardization (Reference 4-1) requires that the main control station be at the boiler front, the current trend appears to require an enclosed, air conditioned operating station. This selection would provide improved working conditions for operating personnel and would also provide an optimum environment for control electronics. Alternate standard designs for other main control station locations can also be developed if justified by demand.

The bridge should be chosen as the location of a secondary control console. The bridge console would be designed as a separate standard propulsion control unit, much as the main console has a separate propulsion section. Additional secondary control locations, such as at bridge wings. engineering office, or special observation stations could be ac coinmodated by optional control transfer switches and interface points on the bridge console.

c. Owner Required and Optional Equipment

Although data loggers and bell loggers appear to be declining in popularity, other equipment that may currently fall into this category is being rapidly developed, and may soon become normally furnished components of automated ship control and supervisory systems. it is, therefore, important to develop a standard control console design which can be arranged to accept interfaces to such optional equipment.

The problem of interfacing to such optional equipment is the same as the problems encountered in accommodating different degrees of automation, or in accepting various technological improvements. The best standard will be one that shows enough flexibility to accept interfaces to at least some optional equipment.

d. Developments in Control System Technology

In formulating control system standards, consideration must be given towards accommodating new technological developments in order to optimize the life span of such standards and extend the benefits that may be derived from having standards. This consideration is one of the most critical in determining the feasibility of a control system standard because an inability to accommodate technical improvements may make such a standard unacceptable

Current developments in control system technology, that should receive consideration in the implementation of standards, are increasing use of digital control and signal transmission, and increased automation of propulsion subsystems, including computer controlled reaction to plant malfunctions.

The impact of these developments on a control system design standard is to limit the extent to which the standard can be applied. Attempting to standardize the control console to a specific internal arrangement would almost certainly ensure early obsolescence. Console designs must remain flexible in order to facilitate incorporation of desirable technical improvements. Standards are best applied to several levels, external to the actual control console, with each level subject to change as required for compatibility with various technical improvements. For example, standardization at the machine module boundary to the control system may be maintained even though *the* signal transmission system may be changed, and standardization of the signal transmission system may not prevent implementation of limited digital computer control within the console envelope. Of course, the state of control system technology at the time the standard is implemented will determine the appropriate levels of standardization.

e. Levels of Standardization

The basic elements of a propulsion control system are the engine room console, the bridge console and various control actuators and monitoring/alarm sensors located on the propulsion machinery. Figure 1 is a block diagram showing the relationship of these elements. *Not* shown are the internal electronics and fluidics systems that perform the control functions needed for a full automation system.

As already noted, standardization of the propulsion machinery itself, both the propulsion engines and the associated auxiliary units, requires that at least some standardization be applied *to* the control actuators and sensors that are mounted on the units. Standardization of these control actuators and sensors improves opportunities for standardization of the system interconnection media (i.e., cables, piping) and interface arrangements on the machine units.

The Maritime Administration guide for standardizing propulsion consoles (Reference 4-1) develops console control features and guidelines for physical arrangement of the various controls. Requirements based on this document also encourages standardization. Together with limitations on size, weight, foundation interface, power requirements, etc., this would permit standardization of console outline and installation

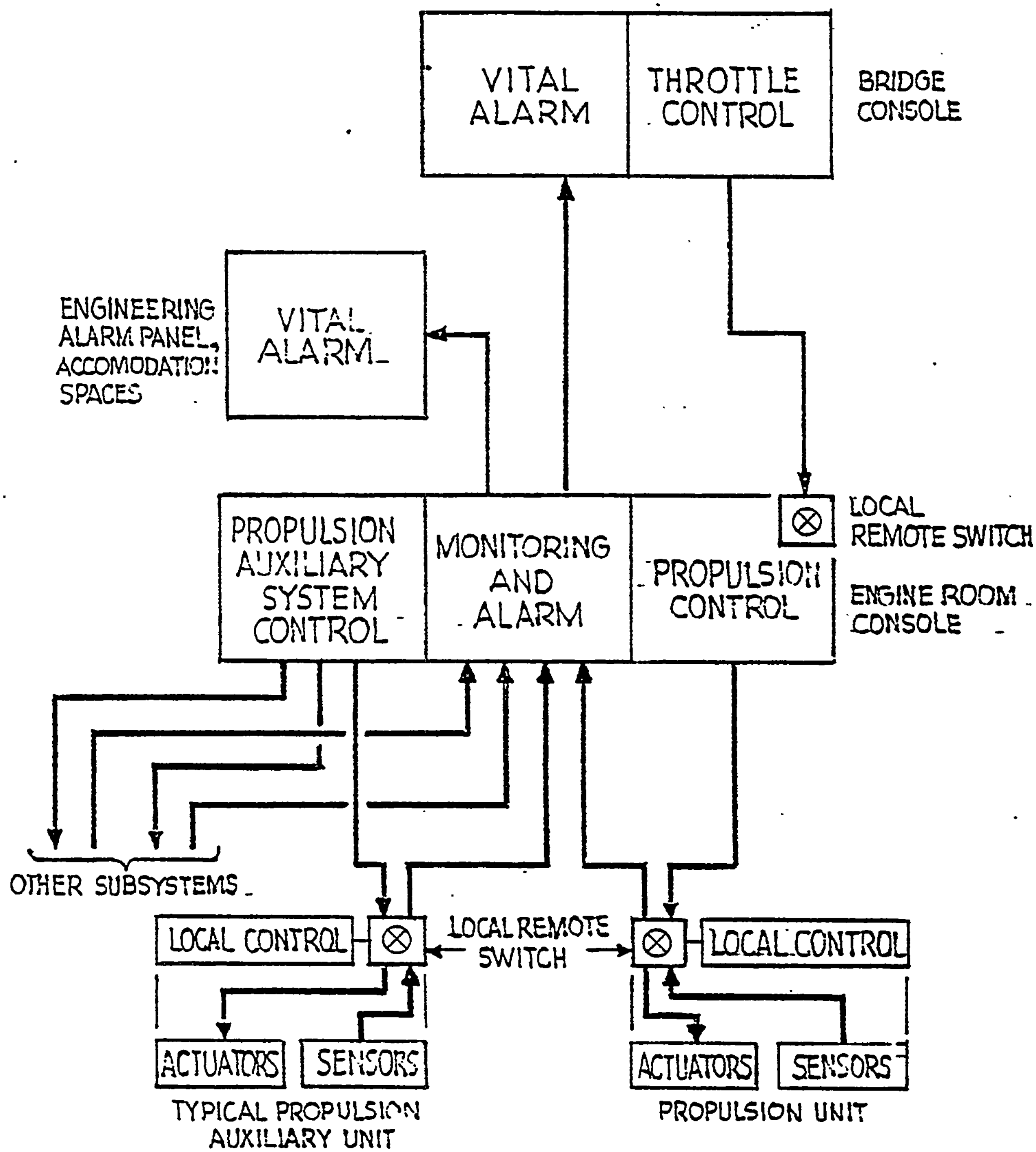

FIGURE 1 -TYPICAL PROPULSION CONTROL ~~SYSTEM~~
BLOCK DIAGRAM

drawings, and system interconnecting hardware.

It is anticipated that a console's internal logic and control hardware are not likely candidates for standardization. Each console manufacturer individually selects internal hardware for optimum performance, price and production methods, and it is expected that restrictions imposed by standardization would be more firmly resisted than standardization in other areas. Standardization in this area is further discouraged-as any possible improvements in design, or any extension of system capabilities that may be obtainable as a result in changes in internal console design, would be restricted by the existence of such standards. Benefits of standardization in this area are essentially limited to maintainability of the console electronics; however, high maintainability can be obtained without resorting to standardized control circuitry. Such features as self-contained trouble-shooting circuits and easily replaceable modules can be required. Therefore, because of the difficulty anticipated in applying standardization, the excessive restrictions that would subsequently be applied, and the doubtful benefits that can be thereby derived, <u>standardization of the propulsion console should not be applied beyond the physical size and weight limitations and the location of interface connections</u>.

The bridge propulsion console and engineer's alarm panel should be considered to be extensions of the basic engine room control system, and standardization should be applied to the same extent as it is applied to the engine room console.

f. <u>Operational Characteristics</u>

In addition to the size, weight, interface characteristics and other previously discussed parameters, the following control system characteristics should be considered as candidates for standardization:

(1) Method of Control

Control actuators can be either pneumatically, hydraulically, electro-mechanically or electronically driven. This choice of actuating media should be made for each of the actuators in a control system, and established as a standard for that system.

(2) Performance Requirements

Performance requirements for each control actuator are pre-determined by the controlled machinery and are consequently established as standards once the propulsion machinery design is standardized.

(3) Number of Control Functions

The degree of automation and the characteristics of the controlled machinery will determine the functions that require remote and/or automatic control. Standardization of the degree of automation and the propulsion machinery will permit standardization of the functions required to interface with the control system.

(4) Number of Monitoring & Alarm Points

This control system characteristic is also largely predetermined by the degree of automation and the controlled machinery.

(5) Control Power Requirements

Characteristics of electrical, hydraulic and pneumatic supplies are essentially standardized at the present time. Power consumption may vary as a result of variations and in equipment layout and differences between equipment procured from various vendors; however, an overall limit on power consumption can be set and should permit sizing of standardized power sources and interconnections.

4. <u>Summary of Technical Feasibility</u>

The solution to the problem of selecting criteria for a standard control *system* design is complicated by the wide variety of systems demanded by different ship owners and operators. In order for a standard to be successful, it must accommodate enough features to be acceptable to most owners, without containing more features than any owner would be willing to buy.

Owners usually choose a control system on the basis of past experience, personal preference, or detailed life cycle cost studies aimed toward optimizing the tradeoff between initial cost and operation expense. In this regard, a control system standard design is extremely sensitive. Changes in several of the design parameters can involve significant changes in a ship's initial cost, and correspondingly large changes in manning and operating expenses.

While the diverse requirements of various ship owners may seem to discourage control system standardization, other considerations add promise to the possibility of standardization. Several shipyards in fact have had success with varying degrees of propulsion plant standardization, indicating that owner acceptance of standardized ships is increasing. The owner stands to benefit by way of reduced initial purchase costs, reduced construction lead time, reduced initial *system* test and troubleshooting time, and less time required for personnel training and ship maintainability.

Where requirements for a variety of designs exists, it may-be possible to satisfy these various requirements with a relatively small group of alternate standards, or by implementation of standards capable of accepting various optional equipment. The same methods of applying standards may allow gradual incorporation of new developments in control capability or system safety, until general industry acceptance makes total revision of a standard necessary.

Thus, technical feasibility of a control system standard depends upon the system's flexibility, as a rigid control system standard is likely to be unattractive to many ship owners, unacceptable to equipment manufacturers and technically unacceptable as a standard due to its inability to provide for future improvements in control and safety.

APPENDIX B.4.a

TRIP REPORT:	Avondale Shipyards, Inc. Avondale, La.
DATE :	October 8, 1974
PERSONS MAKING TRIP:	Mr. N. Maniar, Vice President, Basic Ship Division Mr. J. Lancaster
PERSONS VISITED :	Mr. T. Doussan, Vice President and Chief Engineer Hr. W. Emmons, Engineering Mr. V. Baricev, Director of Purchases

PURPOSE:

To visit Avondale .Shipyards, Inc. (ASI) and solicit comments on M. Rosenblatt & Son, Inc. (MREs) efforts concerning the Propulsion Plant Standardization Feasibility Study as it exists to date.

DISCUSSION:

Mr. Maniar opened the meeting by presenting to ASI the objective and scope of the feasibility study. A discussion of the MR&S forecast and Avondale’s projected plans for construction followed. It was interesting to note that for the greater part, Avondale’s plans and the forecast were in agreement.

After a presentation of the standards candidates, ASI’S comments were requested. Avondale’s concern over the difficulty of producing national standards seemed to agree with the comments offered by other shipyards. The intrinsic capacities and capabilities of each shipyard and the inherent characteristics of each ship causes tremendous difficulty when trying to apply standards. Other problem areas were also mentioned; but underlying this discussion-was the thought that, although these ’problems do exist and should be realized when writing the standards, it does not mean that the standards are not beneficial and workable.

Problems mentioned by Avondale which were not mentioned by any other shipyard were as follows:

- Before the-envelope concept of standardizing can realize ny cost benefits, an engine room arrangement must be developed.

- Ž The standards seem to lack the requirements of responsibility for manufacturers and shipyards to conform - no policing. However, it is MR&S' view that PO' icing would have an adverse affect and that the cost benefit of such standards as proposed should provide enough incentive for cceptance.

- Ž Standards for individual equipment/components should only be written after a survey of what is available has been made. Individual standards should be made *to* comply with what vendors are producing for the largest portion of their business since this is what they base their designs on.

A discussion of possible standardization in the area of purchasing was held with both the engineering and purchasing departments. Engineering's comments were as follows:

Trying to specify the exact piecesof machinery from the exact manufacturer before going to the ship owner for contract although it may be impossible, would cause some tremendous benefits.

- Specification should be written with simplicity in mind.

- The volume of marine business when compared to the volume of shore side business makes it very difficult for the shipbuilding industry to drive the vendors towards what the marine industry wants.

- Specifications should deal mainly with the performance of the machinery.

- It is not believed that a modification of the procurement procedure will decrease time and costs.

When discussing this same topic with the purchasing department, the main idea generated was to have the legal portions of the contracts standardized. When negotiating the contracts with the vendors, the legal clauses, imposed on the shipyard during the signing of the contract with the ship owner, must be passed on. This causes a great deal of delay because of differences from serious contracts. Having a standard "form" contract could decrease procurement time by three to six weeks.

Another area discussed during the meetings held with the engineering department dealt with design time. It was noted that design time has increased tremendously over the years and it is felt that a reduction is necessary. The following were mentioned as the reasons for increased design time:

SMILDEN, A. B.; and GULOWSEN, A.B. "Shipwiring power Cables." Electrical Communication, Vol. 47, N3, 1972,pp. 151-158.

SHIT J.A.: and STEIGER, H.A. "The Selection of Propulsion Machinery for LNG Carriers." Motor Ship, August, 1972, pp. 221-26.

Soviet Shipbuilding. Hyattsville, Maryland: Naval Ship Systems Conmmand, December, 1969.

"Spain's Shipbuilding Vitality." Surveyor, February, 1972, 1972, PP.7-17.

"Steam Propulsion" Marine Engineering Loq, (October, 1971).

SVENNING, B.; BROMAN, S.; and BUTCHER, R.O. "The Periodically Unattended Engine Room on the TT THORSHAMMER." Paper presented at the annual meeting of SNAME, New York, November 11-12, 1971.

SVENSEN, NIELS-ALF. "WhatE veryS hipyard Needs To Know About Marine Heavy Duty Gas Turbines." Paper, Spring Meeting, The Society of Naval Architects and Marine Engineers, April 2, 1973.

TAKEZAWA, 1. Development of the Automated Shipyard. Tokyo, Japan: Mitsubishi Heavy industries, January, 1972.

ItThe Great Electric Ships..." Marine Engineering Loq, Vol. LXXVII, No. 4, (April 1973).

"The Design Requirements for an Unattended Engine Rmm Steam Propulsion Plant." Marine Technology, April 1972, pp. 205-215.

TIKHOHIROV. B. *et* al. "Automation of Ships." Morskoi Flot (USSR). 1971. Translation. Arlington, Virginia: Joint Publications Research Service, January 13, 1972.

" 'Tokyo Bay' First of a Series of Five Container Ships for OCL." Shipping World & Shipbuilder, (,ay 1972).

VANLAER, T.J.H.''Diesel ElectricA.C. Propeller Drives." Holecpost, December, 1970, pp. 76-81.

WOODYARD, D. "shipbuilding in from the Cold." Engineering, July, 1971, pp. 423-428.

More time is being spent corresponding with the manufacturers.

- Ships are mare complex and complicated creating additional design time.

- Machinery is now being designed closer to their limits with a resultant decrease in margin. This causes the shipyards to require closer and additional checking of the analytical work.

- Vendor information seems to be very slow and in some instances withheld.

- For the same basic engine room designed years ago; the “one-manned” engine room requires closer Coast Guard review.

- Talent available is in short supply.

In general, Avondale did not have a jaundiced opinion of the idea of standards, nor did they feel that the standards candidates were workable. They kept an open mind and would accept realistic candidates for standards development; however, they were very helpful in calling attention to certain problem areas. It was feld that, although these problems do exist, the standards were not automatically rejected and are possibly workable.

APPENDIX B.4.b

TRIP REPORT: Bethlehem Steel Shipyard
Sparrows Point, Maryland

PERSONS MAKING TRIP: Mr. A. Isaacson
Mr. J. Lancaster

PERSONS VISITED: Mr. A. Lebrun
Mr. W. Nichols

PURPOSE:

To visit Bethlehem Steel Shipyard (BSS) and solicit comments on M. Rosenblatt & Son, Inc. (MR&S) efforts concerning the Propulsion Plant Standardization Feasibility Study as it exists to date.

DISCUSS1ON:

Mr. Isaacson opened the meeting by presenting to BSS the objective and scope of the feasibility study, and in some detail, the procedure used by MR&S in the classifying, listinq, selectinq and evaluating the standards candidates. This-was briefly-discussed ‘by all in attendance - more specifically, the basis for the criteria used in evaluation of the standards and the matrices were discussed.

Mr. lsaacson then presented the candidates as selected and grouped while soliciting.BSS comments. A lengthy discussion ensued after the presentation of each group (i.e.: standard propulsion plants, modules, envelopes and individual equipment). Detailed points made by BSS are as follows:

1. It is difficult to standardize on SHP ranges since each individual owner has his own requirements. BSS pointed out that they market tankers with standard propulsion plants in exact SHP’S increasing by increments of five thousand (5,000). Mr. Isaacson mentioned that MR&S also had listed them in this manner prior to the last advisory council meeting but was requested to change to a horsepower range.

2. Packaging systems are much more difficult at the-lower levels of the engine room especially on tankers where the engine room is aft-the lower level is tight with large web framing.

3. BSS uses modules as much as possible but must tailor them to each ship design.

4. BSS has made much the same modules as MR&S proposes.

5. Shipping size and crane capacity may prevent development of power unit modules.

6. Buying an outside assembled (assembled elsewhere than at shipyards), package creates a tremendous problem in procurement and coordination.

7. Modules and envelopes must be designed with the flow of piping, walkways, maintenance space, and interfering piping kept in mind. In addition, the need of a facility to turn the module to fit his ship may cause problems.

8. National standards are very difficult to develop because of owner requests, individual ship design constraints, shipyard capabilities and varying interfacing problems.

9. Havy tried to standardize turbo-generators but it was most unpopular with manufacturers. There were no bidders.

10. Standardization of individual equipment would meet with similar resistance.

11. BSS'S largest problem areas are as follows:

    a. A lack of quality control by the equipment manufacturers.

    b. Delivery of equipment, materials and software are late.

    c. Plans to start work do not arrive at the shipyard from the vendors on time.

    d. BSS would like to buy off-the-shelf items and eliminate specials.

In summation, Bethlehem Steel's general comments were that the utilization of standards in propulsion machinery may not be practical. However, they feel that the feasibility study may be important and useful if some of the problems involved in ships machinery installations are reviewed and brought to the attention of the shipbuilding industry.

APPENDIX B .4. c

TRIP REPORT

September 3, 1974
File No. 2650

DATES: 14, 15, 16, 21 August 1974

PLACE: Athens, Greece

SUBJECT: Ship Producibility Research Program

PARTICIPANTS: THANOS KIPREOS, MR&S and

a) Niarchos Shipyards, Skaramanga
Persons contacted: Mr. Lalangas, Naval Architect
Mr. Volikas, Marine Engineer
Mr. Tsaltas, Ch. Engineer
Mr. Zagorakis, Port Captain

b) Andreadis Shipyards, Elefsis
Persons contacted: Mr. Sakelariou, Head of Shipyard

c) N.J. Gaulandris Shipping, Piraeus
Persons contacted: Mr. G. Kondoul is, Port Captain
Mr. Kalonas, Port Engineer

d) Empeirikos Shipping, Coulouthros Co., Piraeus
Persons contacted: Mr. Katevenis, Head, Technical Services

e) Karageorgis M. Shipping, Piraeus
Persons contacted: Mr. Harcharos, Chief, Shipboard Automation Div.

f) "Cherma" Electronic, Piraeus
Persons contacted: Mr. Politis, Head Shipboard Machinery and Automation

1. GENERAL

The purpose of this trip was to obtain shipyard and shipowner views on a) standards/standardization of Marine Propulsion Plant, b) shipyard approach for cost estimating, cost control and scheduling, and c) current and future standardization and automation.

2. DISCUSSION

A "sumnary" of the purpose of the Ship Producibility Research Program as in proposal was provided to all of the above parties. Additionally, the questionnaire included in the MR&S "Guide for Shipyard Visits" was presented to the two shipyards (a & b above); four basic questions were asked of the three shipping companies (c, d & e above) namely, 1) What is the current degree of standardization employed on their ships on the system, sub-system, and equipment level, 2) What standardization would they like to see in the future, 3) What kinds of cost savings and in what areas do they anticipate such, as a result of standardization, and 4) What is present and future forecast degree of engine room automation on board their ships.

Finally, with regard to Cherma Electronics (a major agent involved in market research, supply, and supervision of installation and testing of Bridge and Engine Room conventional and automated equipment and systems) general questions were asked, regarding present and forecast Greek shipping Industry trends and views with respect to standardization and shipboard automation.

The following was the response of the parties interviewed:

2.1 Niarchos Shipyards: Questionnaire will be mailed back to MR&S. Not all of the questions will be answered, as some of these, concerning overhead costs, costs of heat balance preparations, etc., are considered classified information.

General comments: They consider standardization to be a very difficult endeavor, especially in convincing major equipment and piping manufacturers to standardize their equipment. Currently, they only utilize existing automatic boiler control systems on their new constructions. Four of their vessels are equipped with bridge automated collision avoidance systems of varying degree of hard-wired logic system sophistication, on an experimental basis.

2.2 Andreadis Shipyards: Filled-in questionnaire will be mailed back to MR&S shortly. Mr. Sakelariou did not wish to comment on the extent of standardization employed on ships built by the shipyard as well as the orders which the Andreadis Shipping has placed with the Hitachi Shipyards, before consulting with his top aides.

General comments: They would welcome standardization once it has been established. They feel that it would be a difficult undertaking. “When the same manufacturer is coming out with the same model and capacity e.g. pump but for which same model different size piping can be used (i.e., 3/4" and 1"), how are you going to get different manufacturers to agree to standardize their equipment?” Nevertheless, they see definite benefits as a result of standardization.

2.3 N.J. Goulandris Shipping: A fleet of 45 vessels of which approximately 20 are tankers. Of these vessels only one, the "Violando N. Goulandris" an end 1972 construction includes a hard wired alarm, monitoring and control system, and a second vessel the "Paralos" employes an automatic gas boiler control system.

General comments: They would rather welcome standardization since for them it would mean considerable savings per construction. But, to them, standardization goes hand in hand with automation and it is in this latter area that they have objections. They feel that the presen engine room and bridge automated systems are loaded-with problems; e.g. , effects of sea air, vibration, defective system components, etc., on the operation-of the ship, coupled with personnel (or lack of) inexperienced in the maintenance and repair of automated systems at the various ports of call, make such systems very difficult to operate and, in fact, add more headaches.

On the other hand, from the point of view of savings through reduced shipboard personnel, they sited the case of one of their tankers, a 1968 Sikawajima Harima Shipyard 150,000 dwt construction, ACCU classified, in which case the insurance company demanded full crew, as in non-ACCU classified vessels, prior to granting reduced premium.

2.4 Empeirikos Shipping, Coulouthros Co.: A fleet of 21 vessels, mostly tankers, ranging from 65,000 to 336,761 dwt. Eight of these vessels are currently being delivered to them by the Mitsubishi shipyards, and in these new constructions they are already into standardization on the subsystem level, which the Mitsubishi shipyards are providing.

General comments: They are a healthy company, employing three M.I.T. engineers as heads of departments, as contracted to most shipping companies in which the decision makers are still either ex-captains or ex-chief engineers. They feel that they are going to have consider: able savings resulting from standardization.

With regard to engine room automation they are already installing hard-wired alarm, monitoring and control systems on their new constructions, (mostly steam propulsion) with bridge alarm and monitoring but not bridge control. These new systems are designed for a 16 hour unattended engine room.

2.5 Karageorgis M. Shipping, Piraeus: A fleet of 81 vessels, if new constructions are included, half of them tankers, and the rest cargo ships, ranging from 9,400 to 30,000 B.H.P., all but one diesel-propelled.

General comnents: Host vessels built in Japan. New constructions are standardized.

Have contracted with Norcontrol for automation and also have their own automation specialist.

Full automation on all of their vessels, which are all, but one, ACCU classified: computer-based engine room alarm, monitoring and control systems, with bridge control; computer-based satellite Navigation and collision avoidance systems on the bridge.

2.6 "Cherma" Electronics, Piraeus: General comments regarding attitudes of Greek shipowners with respect to benefits through standardization and engine room automation:

a) Reluctance in adopting standardization.

As the situation stands today, shipowners can still command and get quality and expediency from numerous, hard competing, shipyards, which they feel they might lose if equipment and systems become standardized.

b) The fact that they have encountered numerous maintenance problems in those cases where automated alarm, monitoring and control systems have been employed, makes them suspicious and doubting of the effectiveness of these new, expensive, and so far complicated systems. The latter comment is related to the present degree of experience of the shipboard personnel and to the major undertaking necessary to educate them.

c) General confusion in the interpretation of "Automation"

APPENDIX B.4.d

C-E Marine Division
C-E Reference M-74014
June 25, 1974

Ship Producibility Program

Marine Boilers

Meeting Summary

Persons in Attendance:

A. D. Isaacson - M. Rosenblatt & Son, Inc.
E. Thomas - M. Rosenblatt & Son, Inc.
R. B. Hedges - C-E
S. E. Sabo - C-E

Date: June 6, 1974

Place: Windsor, Connecticut

I. General Discussions

M. Rosenblatt & Son, Inc. (MRS) stated that the prime objective of subject program was to reduce the initial cost of building ships to the shipyard without increasing in-service costs. C-E stated that it felt that life-cycle costs should also be considered even if initial costs to the shipyard were increased. Too many vessels are already being built today with low initial cost machinery being installed. Much of this low initial cost machinery causes high continual. maintenance costs resulting in a vessel with high life-cycle costs.

Standardization of machinery components can be considered in various ways. Concerning boilers, operating conditions at the superheater outlet are already fairly standardized, specifically 950°F and 850-900 psig. Some slagging problems have developed as a result of a combination of the higher tube metal temperatures and poorer qualities of fuels being utilized. By reducing the superheater outlet temperature, tube metal temperatures could be reduced, but the overall plant efficiency would be effected, resulting in higher operating costs. Wider tube spacing in a single superheater would also help, but would only extend the time that it takes for the slag to build up and bridge between the tubes. This, however, would require a larger boiler, therefore increasing initial cost. By going to a dual superheater configuration, use of wider tube spacing and a reduction of tube metal temperatures could be realized, but again, a higher initial boiler cost would be incurred.

Specific heat cycles were also discussed, specifically two heater and four heater. Actually, the conditions for these cycles are also fairly standardized, as follows:

	2 Heater	4 Heater
Feedwater (into economizer)	280°F	400°F
Air Heater	Steam	Gas Regenerative
Boiler Efficiency (Approx.)	89.0% - 89.2%	90.3% - 90.7%

Each cycle has its own merits and each owner has his own preferences. Many items must be considered before a particular cycle is selected inasmuch as the initial. cost of machinery for each cycle varies considerably es does the fuel rate. As a result of the present fuel crisis and high fuel prices, considerable interest has again also developed concerning reheat cycles. The initial cost of these plants, however, are quite hign.

The number of boilers installed aboard a vessel also effects initial costs. Obviously, a single boiler ship has the lowest initial machinery cost as compared to a 1-1/2 or 2 boiler ship. If there is a boiler failure, however, the single boiler ship is inoperable. One way of reducing the possibility of failure aboard a single boiler ship, as well as any ship, is by installing a more conservatively rated boiler. C-E has furnished boilers for five single boiler U.S. vessels with conservative furnace ratings (release rates and absorption rates.) The first of these vessels was delivered over eight years ago and, to date, none of these vessels has had an unscheduled boiler shut-down while at sea. In general, however, it still appears that the majority of vessel operators still prefer the two-boiler machinery installation.

C-E has developed a standard series of marine main propulsion boilers. By selecting various standard specific frame sizes (capacities), a series of boilers were developed which allows a shipyard or vessel designer to select a boiler design at an early stage in the vessel's design. This enables the shipyard to realize lower initial boiler costs through reduced engineering, drafting, lead times, etc. (See paragraphs IIA-5 and IIB-2 below for more details.)

MRS stated that although life-cycle costs are important, specific components would probably be reviewed and discussed in detail by committee’s formed from within the industr’y as a result of the information developed by subject study.

II. Ship Producibility Program - MRS Outline

A. Shipbuilding Machinery Fore cast

1. Equipment ordered in the last five years.

(See pages 3 end 4)

Normal (100%) Steam Rate/Boiler (lbs/hr) (10^{-3})

		0-50,000	50-100	100-150	150-200	200-250	250-300	300-350
1969	Commercial		10		2			
	Auxiliary							
	U.S.N.							10
	Auxiliary	4						
1970	Commercial		18	4	4			
	Auxiliary							
	U.S.N.							
	Auxiliary							
1971	Commercial		8	14	3			
	Auxiliary		3					
	U.S.N.							
	Auxiliary	6						
1972	Commercial	2	14	24				
	Auxiliary	9						
	U.S.N.			2				
	Auxiliary	1						
	Waste Heat	48						
	U. S.C.G.	2						
1973	Commercial		26	24	4			
	Auxiliary	4						
	Waste Heat	1						
	U.S.N.			3				
	Auxiliary							
	U.S.C.G.	2						

Domestic Vessel shaft Horsepower -
Number of Main Propulsion Boilers

	0-15,000	15-20	20-25	25-30	30-35	35-40	40-45	45-50	70
1969 Commercial		4	4	4					
U.S.N.									10
1970 Commercial		6	4	8	4			4	
U.S.N.									
1971 Commercial			5		18			2	
U.S.N.									
1972 Commercial	2		1.2	2	4	1 4	6		
U.S.N.									
1973 Commercial			22		4	4	20	4	
U.S.N.						3			
Total No. Ships									
Commercial	1	5	2 4	7	15	9	13	5	
U.S.N.						1			5

2. C-E Equipment presently being built

Seatrain Hull. 103 - main propulsion boilers
Seatrain Hull 104 - main propulsion boilers
DLGN - 40 - auxiliary boilers
IMC/Chevron GT-1 - waste heat boiler
LHA #l-5 - spares

3. Active Orders on Hand

DLGN 36, 37, 38, 39, 40, and 41 - auxiliary boilers
DE-1078 thru 1097 - main proplusion boilers
Navy Hot Plant - Great Lakes Training Center - main propulsion boilers (DE-1078 class)
USCG Icebreakers - auxiliary boilers
LHA #1, 2, 3, 4, and 5 - main propulsion boilers
LASH - Hulls No. 1941-1943, 1949-1952, 2257, 2258 - resin propulsion boilers
Seatrsin - Hulls No. 100, 101, 102, 103, and 104 - main propulsion boilers
FMC/Chevron -Hulls No. GT-1, GT-4, and GT-6 - gas turbine waste heat boilers

4. Projecting boiler orders for the next 10-15 years is just about impossible. Fifteen years ago, very few people would have envisioned that in 1974 U.S. shipyards would be building vessels of 225,000 and 265,000 DWT with up to 50,000 SHP steam turbine power plants.

For the next five years, however, we anticipate that 65-75 boilers will be ordered <u>each year</u> equaling approximately ten million pounds of steam <u>per hour</u> per year which is equivalent to a market value of approximately 28-32 million dollars <u>per year.</u>

C-E would anticipate receiving approximately one-third of this projected business.

5. Plans for Equipment

C-E has already completed the basic engineering and drafting for a standard design series of resin propulsion boilers, both of the C-E V2M8 design and the C-E V2M9 design. Attachments #l & 2 to this summary illustrate the general configuration of each particular boiler design and frame size, overall dimensions, and approximate capacity.

We plan on shipping more and more units fully assembled to the shipyards inasmuch as there appears to be a preference, by shipyards, to purchasing modular units.

The C-E V2M9 boiler was originally designed with the higher horsepower VLCC vessels in mind. With the introduction of higher horsepower vessels to the U.S. shipbuilding industry, we look forward to introducing this design to the U.S. and receiving our first U.S. contract for this boiler design in the very near future.

We are presently reviewing and evaluating a standard design series of auxiliary boilers.

We are presently reviewing and evaluating a standard design series of waste heat boilers for gas turbine and diesel engines.

We are presently involved in a Research & Development program to determine the feasibility of utilizing a coke/oil slurry mixture as a fuel for marine steam applications.

B. Standardization of Propulsion Plants

1. Major Machinery Cost and Schedule Problem Items

a. Steel Shortage - Lead times for material continues to increase, as does the price of steel, making it very difficult to accurately schedule deliveries and develop firm prices.

b. Vendor Items - Prices for many vendor items are increasing at phenomenal. rates and are often being quoted "prevailing price at time of shipment. "

C. C-E Shop Standards - These standards are set by our utility group inasmuch as they have the greatest portion of the work going through our shops. Marine incorporates these standards into our designs to keep our in-house costs as low as possible.

B2) How Standardization Will Reduce Costs end Schedule Time

As mentioned in paragraph A-5 above, C-E has already taken a major step toward standardization with the development of our standard design series for our V2M8 and V2M9 boilers. By industry accepting and utilizing standard (existing) designs, initial costs can be reduced, as follows:

a. A minimum of engineering and drafting will be required for each new centract.

b. Lead times can be reduced inasmuch as drawing and regulatory body approval times are reduced to a minimum.

c. With the availability of standard designs, the naval architect can consult with the boiler manufacturer at an early stage of the vessel design and insure that sufficient space is available for the lower priced standard design unit.

d. Standard (existing) boiler designs reduce performance warranty contingencies inasmuch as the standard unit will be service proven.

B3) Market Offerings - Preferences

Our preferences, and our current market offerings, are the standard design series of V2M8 and V2M9 boilers. Both of these designs utilize welded wall construction in way of the furnace, although the V2M8 can be designed to utilize tangent tube construction, refractory, and double casing. By joining adjacent boiler furnace water wall tubes with a web of metal running longitudinally between the tubes, a gas tight envelope consisting primarily of furnace tubing is constructed. Light weight insulation is then attached to the buckstay stiffeners, to contain the heat generated by the operating boiler, with a light gage met al outer cover. This type of construction provides a virtually fully water cooled furnace with little or no exposed refractory, thereby reducing boiler maintenance costs.

Another preference would be to utilize more conservative furnace ratings. Absorption rate (BTU/hr. sq. ft. of radiant heat absorption surface) is one excellent criteria for rating a furnace inasmuch as it indicates the loading on the exposed heating surfaces of the furnace. By fully water cooling the furnace vs. only the side, roof, and rear walls, a lower furnace rating, for the same capacity boiler, can be attained. Although the more conservative furnace rating results in a larger boiler and higher initial cost, the increased reliability and reduced maintenance costs, over the life of the vessel, far exceed the additional initial cost.

We would also prefer to deliver boilers assembled. In this manner, we are able to reduce the men hours required to erect the boilers because we can assemble them on a production line basis. Also, by delivering boilers assembled, responsibility for material and workmanship deficiencies lie solely with the boiler manufacturer. This sole-source responsibility eliminates considerable time and expense normally spent trying to determine responsibility by the shipyard and the boiler manufacturer.

For higher horsepower vessels, we definitely prefer marketing boilers of the V2M9 design. One of the features this boiler design incorporates is tangential firing. Fuel oil burners are located in each corner of the furnace and are directed tangent to a small imaginary circle in the center of the furnace. The fuel oil particles violently scrub against each other and, as they spiral upward, burn completely before passing into the banks of boiler and superheater tubes. The combustion process in these boilers has been complete to the point that vessels which have these boilers on board have reported operating at as low as 1-1/2% excess air.

C. Lower Installed Machinery costs

Many of the items which effect the installed cost of machinery have already been discussed, however, the one item that will have the greatest effect on the initial cost of the vessel will be the utilization of standard existing designs, whenever possible. By duplicating existing or standard units, engineering and drafting, for the boiler, are kept to the bare minimum.

Early contact between the vessel designer and boiler manufacturer will also enable the shipyard to realize lower installed costs. By reviewing available standard boiler designs at an early stage of vessel development, sufficient space can be made available within the vessel's machinery spaces so that a standard design can be utilized. This will eliminate the need for "custom" designing a boiler to the space left after the rest of the machinery has been alloted space. Obviously, this custom designing increases the original cost of the equipment considerably.

III. Comments

Although we realize that the prime objective of this program is to reduce initial costs of constructing ships, we feel that one must also not lose sight of life-cycle costs. For example:

> To build ships today, particularly a large VLCC, ULCC, or LNG carrier, enormous initial capital investments, are required. When one of these vessels is out of commission, the demurrage rates are tremendous. If one considers, for a moment, a shoreside utility power plant, the amount of money expended to purchase the boilers is approximately equivalent to the money expended for the turbines and generators. Within the shipbuilding industry, however, the money expended for a vessel’s boilers is only about one-half of that expended for the vessel’s turbines end gears. Just as in the utility field, it has become very expensive in” the marine industry to have a ship inoperative. Therefore, it appears that the more conservative furnace ratings as utilized in the utility industry, should be considered for marine applications. The small increase in initial cost for the more conservative boiler will seem small in comparison with the overall initial cost of the ship, but should pay for itself many times over within the expected life of the vessel by increasing reliability and reducing maintenance.

Appendix B.5

B I B L I O G R A P H Y

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